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ASSESSMENT OF A PROTOTYPE CHEMICAL PROTECTIVE UNDERGARMENT DURING SIMULATED FIELD DECONTAMINATION

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13. ABSTRACT *(Maximum 200 words)*

A simulation study was conducted to assess the feasibility of carrying out a field decontamination of a nuclear/biological/chemical (NBC) ensemble based upon a prototype chemical protective undergarment (PCPU). Six pairs of subjects wearing the ensemble were sprayed with a dyed tracer agent and followed a mutual serial process to replace the PCPU and other chemical protective gear. Coveralls were worn underneath the ensemble to show traces of the simulant acquired in contaminative contacts. Results were that all 12 subjects became simulant-contaminated; probabilistic extrapolation predicts a success rate of only 8 in 1000. Certain steps in the decontamination procedure were identified as having significantly contributed to the probability of contamination. Simulation completion time was comparable to that of the equivalent procedure for MOPP4. A questionnaire on subjective perceptions revealed that subjects underestimated the degrees of hazard associated with certain steps. Although training and procedural/instructional improvements can reduce the likelihood of contamination, some of the hazards are a direct consequence of the PCPU design. Recommendations are made for changes to the PCPU design and the way it is utilized in order to reduce the hazards of undertaking a field decontamination with a PCPU-based NBC ensemble.

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Preface and Acknowledgments

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Assessment of a Prototype Chemical Protective Undergarment During Simulated Field Decontamination

Introduction

This study concerns the use of chemical-adsorptive undergarments for individual protection against nuclear, biological, and chemical (NBC) threats. Prototype undergarments, which are worn under a soldier's field clothing, such as the Battledress Uniform (BDU), are currently being assessed for general feasibility. The present study focuses on the behavior of doffing such garments. With respect to present concerns, the feasibility of a Chemical Protective Undergarment (CPU) is a matter of its ease of removal during the decontamination of individuals under field conditions. Chemically contaminated garments must eventually be removed and replaced; therefore, a soldier must be able to doff them without becoming contaminated while doing so.

A prototype CPU was examined in the present study, and will be referred within this document as the PCPU to distinguish it from current issue CPUs. This PCPU consists of a lower garment with elasticized waistband and ankle cuffs, and an upper garment with zippered front, a hood with hook-and-pile fasteners, and elasticized wrist cuffs. The primary difference between the CPU and the PCPU is that the former is form-fitting whereas the latter is loose like a sweatsuit. Present concerns focus not on the garment details but rather on the basic concept of the loose two-piece PCPU set. For this reason, the study used nonprotective conventional garments of similar design to simulate the protective attire.

Both the CPU and the PCPU differ from the current chemical protective (CP) suit, the Battledress Overgarment (BDO), which consists of a zippered coat and trousers with zippered cuffs. The BDO is worn as the outermost layer of clothing. The protective BDO is combined with rubber gloves, overboots, and a full-face respirator, or mask, with an impermeable hood attached. The BDO is the basis of the Mission-Oriented Protective Posture (MOPP); there are five levels of MOPP depending on how much of the protective gear is used. In MOPP0 the mask is carried, the BDO and the rest of the gear are either carried or kept at hand. Donning the BDO (with jacket left open) raises the level to MOPP1. Adding the overboots achieves MOPP2; the mask and open hood, MOPP3. MOPP4 is reached by donning the protective gloves, zipping the jacket closed, and securing the mask hood. The MOPP system is meant to be flexible, and use of the gear can be modified in accordance with weather, activity level, and threat information (Department of the Army, 1985b).

As the MOPP level increases, combat power and work efficiency are reduced substantially, particularly in hot weather (Department of the Army, 1985b). The PCPU is designed to produce less thermal discomfort and allow greater freedom of movement than the BDO.

In the decontamination of a soldier in contaminated MOPP gear, the mask and hood are cleaned of the chemical agent, and the BDO, gloves, and overboots are replaced with new ones. This decontamination may be performed on large groups in an organized manner ("deliberate troop decon") or on smaller units under less secure conditions ("hasty decon"). The worst-case scenario is that in which a small number of soldiers, using only the resources carried with them in the field, attempt to conduct hasty decon in contaminated terrain. A hasty decon performed improperly will at best be inefficient and at worst produce casualties. This danger necessitates that hasty decon follows a detailed, standardized procedure.

The hasty decon procedure for replacing MOPP gear (Department of the Army, 1985a) uses a buddy system, in which one soldier assists in decontaminating the other, and then the roles are reversed. The soldiers have with them materials for decontaminating skin and equipment, and the new replacement BDOs, gloves, and overboots. The hood and mask are first cleaned of contamination. The BDO jacket is removed and placed on the ground, with the lining side up, which creates a safe zone. The BDO trousers are removed over the overboots. Next, as the overboots are removed, the soldier steps onto the safe zone. Gloves are removed, and the new BDO is donned, followed by new overboots and new gloves. The hood is then secured, and the soldiers switch roles and repeat the process. If, at any point in the process, soldiers suspect that contamination has been spread to the skin or the undergarments, they are to stop the procedure and decontaminate immediately using the skin decontamination kit.

The present study uses a similar approach for the prototype PCPU. However, no provision was made to interrupt the procedure and use the skin decontamination kit when contamination of the skin or undergarments occurred. The protocol for hasty decon with PCPUs is given in Appendix A. The primary research issue was whether a safe doffing procedure is possible; the proposed procedure was assessed for effectiveness and safety, and modified as needed. After the procedure for doffing the PCPU is made as safe as possible, any remaining hazards (which are nonprocedural in origin) can be addressed via recommendations for structural redesign of the garments.

Hazards Associated with Doffing the PCPU

The use of PCPUs presents particular problems for hasty decon that do not arise with the BDO or other CP overgarments. These problems stem from the layering order of the soldier's total

attire. Consider a soldier in extant CP gear who has been exposed to a large amount of a liquid chemical agent, such that his or her entire outer surface must be considered to be contaminated. In the standard MOPP4 configuration, this surface region consists of overboots, overgarment set, gloves, hood, and mask front. Between these regions and the soldier's skin are up to two layers: two on the feet (socks and combat boots), two on the torso and limbs (BDUs and undergarments); one on the hands (glove liners); and none on the head. Although these layers do not provide chemical protection per se, they will have been protected by the CP overgarment such that, when the contaminated overgarment is doffed properly, the clothing beneath is not contaminated. In the case of the prototype PCPU, however, there are fewer layers between the contaminated garments and the soldier's skin: one fewer on the torso (conventional undergarments only), and none on the limbs.

Thus the removal of a contaminated PCPU leaves the soldier much more exposed than does the removal of a CP overgarment. Although both cases present the hazard of the soldier becoming contaminated from his or her CP garments in the process of removing them, it is reasonable to expect that the probability of recontamination during hasty decon will be higher with a PCPU than with a conventional CP overgarment.

The doffing of a PCPU is also complicated by the functional nature of the clothing in respect to the rest of the soldier's attire. The soldier's BDU must be considered to be entirely contaminated such that the uniform must be removed and discarded; in order to remove the BDU trousers, the overboots and combat boots must be removed, which leaves the feet protected only by socks. The trousers must be removed without contaminating the feet; so too must the lower PCPU. The removal of each PCPU item risks contamination of the underlying dermal areas; e.g., the waistband of the lower garment must be manipulated without contaminating the midriff region. The feet in particular are at risk, due to the layering of garments; i.e., the combat boots, which must be kept free of contamination, have their shafts between two contaminated layers (the overboots/BDU outside, and PCPU inside). Hence the hasty decon with the PCPU is not a straightforward removal of an outer contaminated layer from an inner safe layer, as it is with a CP overgarment.

Concern with the aforementioned problems is the rationale for the proposed protocol for hasty decon of PCPUs. The authors make several assumptions in proposing this procedure: 1) that the BDU is to be discarded and that a replacement will be issued along with replacements for the CP items (exclusive of the mask); 2) that combat boots and socks are not to be replaced, but are to be reused; 3) that the combat boots have not been pretreated with a chemical agent-resistant coating (CARC); and 4) that expediting the removal of garments by cutting or rending them is not to be recommended as part of a standard protocol.

Tracer Methodology

The primary safety hazard in hasty decon is contact of the soldier's skin and any surfaces of the protective clothing that have become chemically contaminated. In the present study this contact was operationalized via a harmless, detectable substance (tracer agent) applied to the garments to simulate contamination by a chemical weapon. The dependent measures are based upon the extent of tracer acquisition by the subject on unprotected surfaces (skin and/or nonprotective garments). This acquisition can be measured both as the number of contact points and as the total area of contact (dependent metrics are discussed infra). Tracers have been used quite successfully in studies of pesticide application (Fenske, Leffingwell, & Spear, 1985), in which the contaminant is airborne. The method is equally applicable to the assessment of PCPUs, in which the primary route of contamination during hasty decon is via surface contact.

The rationale for choosing this direct simulation of contamination was that the proposed doffing procedure is both inherently complex and subject to some inevitable variability in the biomechanical details of its execution. Alternate approaches to quantifying contact between skin and contaminated surfaces seemed of questionable utility. Self-report by subjects would likely produce errors of omission, and possibly of commission. Visual observation of the subjects by the experimenter would likely be incomplete and ambiguous. These shortcomings would cause a loss of internal validity. Either of these indirect methods alone (or their combination) would also slow down the decontamination process, reducing external validity. Although logistically costlier, the tracer method provides cleaner and more interpretable data. It was decided that the tracer method, supplemented by visual observation, was optimal for the purpose at hand.

Previous Use of Tracers in Assessing CP Clothing

The tracer approach has been used recently in two studies of CP attire. In both cases, a Tyvek(R) coverall worn underneath the CP gear represented the subjects' skin for recording tracer contamination. Both studies used a tracer based on polyethylene glycol (PEG-200), which has long been used to simulate H agents, and is medically innocuous. Alternate simulants, such as methyl salicylate and diethyl malonate, require medical prescreening.

Harrah, Bruno, and Weaver (1990) used a mixture of PEG-200 and FD&C blue food dye #1 to study 121 Marines at hasty and deliberate decon of a CP overgarment and other current CP gear. Despite detailed instruction and practice, subjects received tracer contamination to an unsatisfactory degree, especially in night decons. Harrah et al. recommend the use of tracer agent as a training tool as well as an investigative one.

Blewett, Jones, and Arca (1991) used a tracer to assess a form-fitting CPU used by Special Operations Forces and tank crews. The simulant was a solution of 50% PEG-200, 50% H_2O, and 0.5% [sic] blue food dye. Although no explanation is given for this mixture, it is presumable that the water was added to facilitate atomization. Transfer of contamination was found to be uncommon.

Considerations in the Choice of a Tracer Agent

With respect to methodology, a chemical agent simulant should remain on the surface of the garments to which it is applied, rather then soak in. It should readily transfer by tactile contact, and its presence should be visually detectable by the experimenter. It should be nonvolatile so that it will last through a lengthy experiment without desiccating. These requirements suggested a pigmented, nonvolatile semiliquid of viscous and tacky consistency. With respect to the welfare of the subject, the tracer agent should be nontoxic, nonirritating, and easily removed from the skin.

Field characteristics of liquid chemical agents are varied, but it is preferable that they be visually innocuous (i.e., transparent and colorless), although some are not (lewisite, tabun, brombenzylcyanide, and the mustard compounds, which are yellow or brown). There are two tactile properties of relevant interest. One is that many blister agents (e.g., lewisite, mustard-lewisite, and diphosgene) occur in an oily form, which has the tactical advantage of increasing their effective dermal spread. The other is that some agents are deliberately concentrated to increase their persistency, either directly, as with certain blister agents (e.g., HN-3), or indirectly via decreased volatility, as with thickened soman (VX, VR-55).

It is preferable that a simulant be of low salience to subjects, who are supposed to be avoiding contact with a hazard which is a) presumed to be ubiquitous but b) of unknown actual extent and location. Nevertheless a simulant must be clearly visible to the experimenter for measurement purposes.

For the present study, the tracer agent consisted of vegetable dye in a base of a commercial, nonprescription skin lotion. This mixture possesses the requisite physical consistency and visual properties and is medically innocuous. It was decided to compound the tracer agent to be olive drab in color: dark enough to be detectable upon inspection but less salient than hues of some live agents. It was reasoned that, using a light color for the coveralls serving as the subject's "skin" and a dark color for the PCPU, any tracer acquired by the subject would be obvious to the experimenter during measurement, but less noticeable by the subject during acquisition. The tracer agent would be easily detectable on the light-colored coveralls, which would aid in the detection of

minute amounts of it, as well as aid post-trial analyses of the routes of contamination. Since some chemical agents can be effectively invisible, it was deemed important to minimize a subject's likelihood of awareness of the fact if he or she had been "contaminated." Subjects might be conscious of tactile contact with tracer-contaminated surfaces, but should not be able to visually recognize a particular surface as a tracer-contaminated one; nor should they be aware of the further spread of tracer from one region to another (e.g., they might get it on their arm and then unknowingly brush it onto their leg). The choice of an olive drab tracer for use in this study struck a balance between experimental measurability and simulation realism.

Possible Dependent Measures

Several dependent measures can be derived from tracer presence on a subject, including the following:

Number of contamination loci. This is the number of discrete loci of tracer acquisition by the subject's skin. The distinction between loci that are proximal versus connected is arbitrarily made via visual assessment by the experimenter.

Number of contamination events. This is the number of times that tracer is acquired. The distinction between this and the previous measure is that certain chemical agents will produce noticeable effects immediately (e.g., phosgene oxide, mustard-lewisite, ethyldichloroarsine), such that the soldier will be alerted to conduct personal skin decontamination; in these cases the same dermal region may later become recontaminated. Agents that do not produce noticeable effects until after a long delay (e.g., HD and the nitrogen-mustard compounds) may go unnoticed and thus may be acquired more than once on the same dermal location, in which case the second occurrence is of less relevance given that the soldier has already been contaminated. (This metric is taken in an ongoing manner throughout the trial and is subject to errors of omission.) It is also the case that a single contaminative contact event may leave tracer on more than one locus.

Total area of contamination. This metric can be estimated utilizing the standard methods of calculating the extent of burns (Harkins, 1942), in which the human body is mapped out into regions with designated percentages of the total surface area. Areas of tracer contamination which are too small to be accurately quantified in this way can be directly measured in cm^2. Contamination area is chosen in lieu of the acquired tracer's volume or mass, which would be both awkward to measure and of little more import than the area. An exception in which the actual volume of tracer would be relevant is the case of agents which spread beyond their initial region of contact. They may do this as a result of 1) having an oily consistency (e.g., CA, CX, HL, L, PS, ED), 2) being water-soluble and spreading with the flow of

perspiration (e.g., L, PD) (Birmingham, 1991), or 3) releasing vapors which are hydrolyzed by perspiration (Just, n.d.) rendering them acidic (e.g., CG) or toxic (e.g., L, HS). If agents with these properties are of particular concern, it may be safe to assume that acquired tracer volume is highly correlated with contamination area. Specific concerns for the properties of particular agents, however, were beyond the scope of this study.

Amount x vulnerability. The total area of each locus of tracer acquisition can be weighted by the significance of the body area to generate a score for the severity of contamination. This is relevant only for some chemicals: a thickened nerve agent can be fatal due to systemic consequences regardless of the locus of its initial contact (Birmingham 1991), whereas a given nonlethal dosage of blister agent may be variably incapacitating depending on where it is acquired. There can be two weights associated with each part of the body: 1) the functional vulnerability of the soldier with respect to the body region (e.g., hands = high, elbow = low); and 2) local dermal penetrability (Ikeuchi & Kuno, 1927, Burch & Sodemann, 1944, and Mali, 1955, all cited in Tregear, 1966), the relevance of which depends on the agent's water-solubility and its viscosity (Tregear, 1966).

This amount x vulnerability measure was not utilized in this experiment. The relative significance of the body area is difficult to assess, and no attempt was made to do so for the present study. The measure of contamination area was intended to be used, but the form the data took precluded its meaningful employment, as discussed infra. The other two metrics, number of contamination events and number of contamination loci, were each utilized in several forms.

This study was undertaken to answer several questions. Is it possible to safely execute a hasty decon with a PCPU-based NBC posture? If it is not possible, then what features of the garments could be changed to make the process safe? If a safe hasty decon is possible, then how feasible is the procedure for the end user?

Comparisons can be made between the steps in the decontamination procedure to see if the hazards can be isolated and related to design features; if particular steps are significantly more hazardous than others, then we can justify making procedural changes or design recommendations to correct particular problems.

In the interests of maximizing the amount of information that could be obtained from the study, a worst-case scenario was used for the simulation. This scenario assumed the following conditions:

1) The two soldiers were alone in the field, far from medical support or "deliberate decon" facilities, with only the resources carried with them.

2) Each soldier carried a personal decontamination kit and a set of replacement CP gear consisting of PCPU, overboots, glove liners, CP gloves, and BDUs.

3) The soldiers were attired in the PCPU-based ensemble and had earlier been exposed to a large amount of liquid chemical agent over most of their outer garments.

4) The soldiers were presently in heavily-contaminated terrain.

5) The remote location and the temporal expiration of the protective properties of the contaminated PCPUs necessitated that a hasty decon be conducted.

6) The CW agent, although ubiquitous, was not visually detectable.

7) The agent was of high toxicity.

8) The agent was of rapid effect.

9) The agent was of high persistency.

10) A contaminated individual would not necessarily experience any somatically localizable symptoms prior to becoming incapacitated.

11) The combined effects of the agent and antidote would be incapacitating to a degree that a contaminated-and-injected soldier could not be relied on to continue to effectively assist in the decon of his or her buddy.

Two additional assumptions were made in interpreting the data obtained from the simulation:

1) Any contamination of the skin or the underlying garments would be taken as evidence that the hasty decon procedure (as performed) was unsafe.

2) Contaminants spread to the skin or the underlying garments unknowingly during the hasty decon procedure would not be treated with the skin decon kit and would result in a casualty.

Thus the scenario necessitated that subjects avoid any amount of contamination at all costs, since contamination in effect meant the casualty of one or both members of the pair. These severe conditions were intended to facilitate examination of the causes and routes of contamination, by magnifying both the likelihood of contamination and the severity of its consequences. They were not intended to represent either the typical use of these garments under NBC conflict conditions, or the actual consequences of any particular CW agent.

Method

Subjects

Subjects were obtained from among enlisted personnel assigned to the U.S. Army Natick Research, Development and Engineering Center. Participation was limited to persons found by the Natick Medical Officer to be in good physical health. Potential participants were asked to volunteer after being informed of the purpose of the study, the nature of the test conditions, all procedures affecting a participant's well-being, and the rights of participants to withdraw at any time without penalty. The experimenter adhered to AR 70-25 and USAMRDC Regulation 70-25 on Use of Volunteers in Research.

Subjects consisted of 10 males and 2 females. Anthropometric data are given in Table 1; the estimated dermal surface area of each subject was computed by a program based upon a NASA nomogram (NASA, 1989). Subjects were run in pairs, as the hasty decon procedure prescribes; each member of a pair underwent simulated decontamination. There were no mixed-gender pairs. The total duration of a subject's experimental participation was 2-3 h.

One of the subjects (#10) also assisted in the experiment, and observed several pairs of subjects in the hasty decon simulation prior to undergoing it himself.

Apparatus and Materials

Tracer agent. The tracer agent, or simulant, consisted of vegetable dyes FD&C Green, FD&C Red, FD&C Yellow #5 and Yellow #4, and FD&C Blue #1 in a base of a commercial, nonprescription skin lotion, with a small amount of water added as a thinner. The approximate proportions were 95% lotion, 5% water, and 0.25% dye. The tracer agent was olive drab and opaque; its particular color properties were contrived to facilitate illuminated examination, with a technique described infra (under "Examination Lights"). A manual atomizer was used to apply the tracer agent.

Garments. Hooded cotton sweatsuits were used to represent the PCPUs. The top garments were black with a full zippered front; the lower garments were black or dark green. Zippered Tyvek(R) coveralls were worn under the PCPUs; these functioned as the subjects' "skin" for manifesting contamination. The coveralls were one-piece zippered garments, either white or light blue depending on size. Standard temperate-climate BDUs were worn over the PCPUs; size restrictions required two subjects (from different pairs) to wear tropical weight garments for some portions of the simulation. Overboots were the CP footwear covers; these were chosen for safety considerations because they gave better traction than the green vinyl overboots (GVOs) on surfaces contaminated with the simulant. Size constraints required one subject to wear the GVOs. M-40

Table 1. Anthropometric Data of Subjects ($\underline{N}$ = 12)

Pair/	Subject	Age	Sex	Height (cm)	Height %ile *	Weight (kg)	Weight %ile *	Estimated Dermal Area (1000 cm^2)
I	1	22	F	168	80	64.41	65	16.253
I	2	28 ‡	F	157 †	15 †	53.52 †	15	14.487 †
II	3	21	M	178	65	81.65	65	19.08
II	4	19 †	M	170	20	63.50	10 †	16.43
III	5	20	M	178	65	68.49	20	17.313
III	6	23	M	183	85	81.65	65	19.257
IV	7	25	M	180	75	81.65	65	19.257
IV	8	20	M	185 ‡	90 ‡	81.65	65	19.433
V	9	20	M	180	75	81.65	65	19.257
V	10	25	M	180	75	78.92	55	18.903
VI	11	23	M	170	20	73.03	35	17.94
VI	12	20	M	178	65	94.35 ‡	90 ‡	20.67 ‡
Median		21.50	-	178	--	80.29	--	18.992
Mean		22.17	-	176	--	75.37	--	18.19
♀ Mean		25.00	-	162.5	50	58.96	40	15.37
♂ Mean		21.60	-	178.2	65	78.65	55	18.754

* Based upon U.S. Army population data from Gordon et al., 1989. Individual height and weight values are matched (within sex) to the nearest percentile multiple of five.

† Minimum observed value.

‡ Maximum observed value.

masks with canisters were worn without the hood, which was functionally replaced by the PCPU hood. Butyl gloves with cotton liners completed the PCPU-based NBC protective posture assumed for the simulation.

Examination lights. A 12,500 candlepower halogen flashlight was used both to examine the subjects for tracer during the simulation, and to inspect the coveralls afterwards. A military angle flashlight with blue and red filters was also used for these examinations. The chromatic properties of the tracer were such that, under blue illumination, it appeared red, but only if it were on a light substrate. Hence the light-blue coveralls were examined under blue light. This made the tracer contrast chromatically with the background without changing the appearance of the coveralls. The white coveralls were examined with red light, which caused the tracer to appear darker in contrast to the coveralls. Both coverall types were also examined with the intense white light.

Printed instructions. The "PCPU Hasty Decon Procedure" was printed in large type, one primary numeric step to a page, with substeps, such as 4a and 4b, on the same page. Subjects were told that these pages represented instructions that would be printed on the PCPU packages. These instructions appear in Appendix A. Very minor changes were made in the text after the first two trials were run; these changes were linguistic and not procedural.

Environment. The study took place in the Arctic Dressing Room of the Climatic Chambers Building at Natick. One end of the room contained a dressing chamber; the middle section of the room was used for garment fitting and storage. The other end of the room was used as the simulation area (see Figure 1). A 2m x 4 m rectangular portion of the floor was designated as the contaminated terrain. Two layers of canvas dropcloth with a nonstandard camouflage pattern were secured to the floor with duct tape, and surrounded by a 22 cm border of intermittent nonskid rubber tape. A clear floorspace of at least 0.5 m was maintained around the contamination area with the exception of one of the short ends and an associated corner, where partitions in an L-shape formed a backguard for spraying the tracer agent. At this end was a small table upon which were placed the instruction sheets; next to this was a pail containing a soap solution and sponges, which were used in lieu of chemical decontamination cloths. Throughout the experiment, the room was maintained at 15 °C with 75% relative humidity and negligible windspeed. Fluorescent lighting provided somewhat less than office-level illumination, and the ventilation/cooling system provided a marked but not intrusive level of white noise.

Data collection materials. A form containing an outline drawing of the dorsal and ventral views of a supine human body was used to record both tracer acquisition and contaminative contacts. The location, number, and size of contaminations were indicated

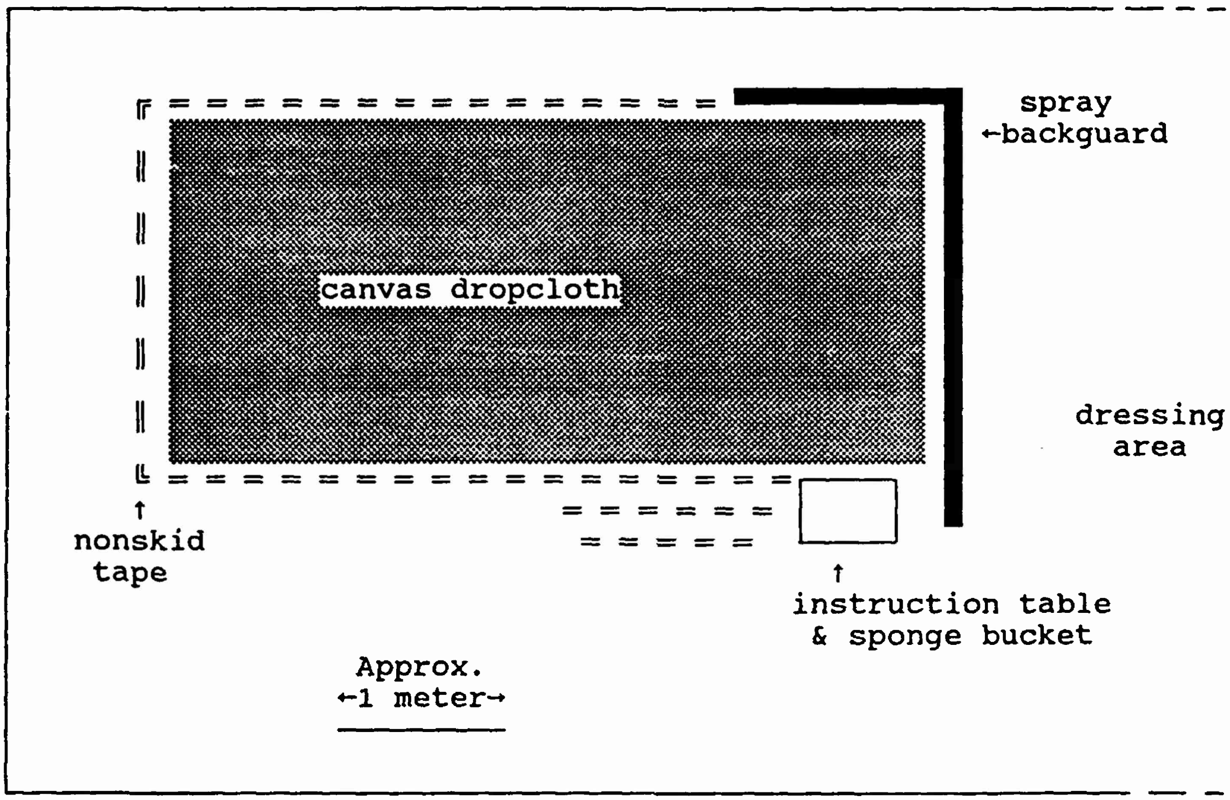


Figure 1. Floor plan of the simulation area of the experimental chamber (approximately to scale).

graphically on the drawing; cause and size were indicated textually. (These forms were similar to the somatic maps in Appendices D and E.) Other notes were made on these forms as needed (e.g., tracking the continued contaminated status of non-coverall surfaces from one procedural step to the next). A digital stopwatch with 0.01 s resolution was used to measure step durations, which were recorded manually on a printed list of steps. A one-page questionnaire (see Appendix B) was used to assess subjects' perceptions of hazard associated with the steps of the hasty decon procedure.

Procedure

Garment fitting. Prior to the simulation, each subject was fitted for two sets of the PCPU-based attire. The subject's height and weight were also recorded at this time.

Dressing. Subjects first changed into coveralls and socks. The wrists and ankles of the coveralls were secured with duct tape, and the ankles were tucked into the socks. For one subject (a 62" female), excess material of the coverall was gathered and folded over at the waist, and secured with tape to provide a fit consistent with that of the other subjects. The PCPU set was donned next, with the top worn outside the waist of the lower garment. BDUs were then donned; the PCPU top was tucked into the BDU trousers. Combat boots (which were the subjects' own) were donned next; the cuffs of the BDU trousers were only partially bloused, in order to aid their later removal. Overboots were worn with the shafts on the outside of the BDU trouser legs. Gloves were then put on inside the BDU sleeves but over the PCPU sleeves. Masks were donned after a prebriefing of the subjects had been completed, and the PCPU hoods secured over the masks.

Prebriefing. Subjects were prebriefed in the decon protocol and its rationale. The more complex steps in the procedure were singled out for detailed explanation and illustration. There was no training or practice session. Subjects were told that they would be able to ask questions at any point, and that several time-outs would be called in which they would be examined for tracer acquisition.

The simulation was described to the subjects as a worst-case scenario, in which they were in the field far from medical support or facilities for deliberate decon, and both their external attire and the environment were heavily contaminated by a highly toxic agent of rapid effect. They were told that any amount of dermal contamination would be considered a casualty, and hence a failure of the hasty decon, and any amount of nondermal contamination (e.g., the nonprotective combat boots) would be considered a failure of the hasty decon and a potential delayed casualty. Subjects were instructed to perform only as quickly as they felt it was safe to do, to take as much time as they needed but no more.

Simulant application. The pair of subjects then entered the contamination area. The tracer agent was sprayed onto each member of the pair, with emphasis on areas that were more likely to be a source of secondary recontamination (e.g., hands and forearms, garment fastenings, elbows and knees); it was neither practical nor necessary to apply the tracer thickly over a subject's entire person. The simulant was also applied to the "ground." It was assumed in the simulation that the BDUs were to be considered saturated with the agent; hence, tracer application had to be repeated at several points in the simulation. When the pair completed step 4a, the simulant was again sprayed onto the passive subject on the PCPU surfaces just revealed; and again on the calves after step 5a. When the subjects' roles were reversed, the soldier to be decontaminated was sprayed again to counter any loss of the initial application. Care was taken to utilize the same amount of tracer on each subject. Approximately 400 mL of simulant was used per pair of subjects.

Hasty decon simulation. After the initial application of tracer agent, the two subjects proceeded to follow the protocol for hasty decon (Appendix A), guided by the experimenter, as needed. One subject (randomly chosen) assumed the active role and followed the printed instruction to decontaminate his or her buddy; the other subject in the passive buddy role received new garments. The new replacement garments were simply handed to the recipient by an assistant. The roles were then reversed and the procedure repeated.

The passive subject was not shown the instructions, but received appropriate instructions verbally and gesturally from the active subject. The procedural steps and substeps were timed. The timer was stopped for the duration of any extemporaneous instructions or coaching. Instructional pages were turned by an assistant, in order to prevent the pages from becoming a spurious route of contamination. Departures from the particulars of the procedural instructions were permitted if the pair encountered lengthy or insurmountable problems. Throughout the simulated decontamination, any observations of what appeared to be contaminative contacts were noted, and, if needed, the subject was examined for evidence of the tracer. At certain predetermined points the subject's coverall and/or socks were examined for tracer as a matter of procedure regardless of whether there was suspicion of contamination. If the pair caused a contamination without their apparent knowledge, it was not disclosed to them. At the point of role switching, the subjects had the option of retaining the first soldier's doffed PCPU "safe zones" or of discarding them as they saw fit, depending on their own perceptions of safety. If the first subject became a "casualty," the pair continued regardless, nor did subjects stop to simulate personal skin decon or atropine administration.

Undressing. After a pair of subjects completed the hasty decon, their coveralls were at risk of spurious "contamination" external to the simulation. Therefore the subjects doffed the outer garments in the contamination area, and then moved away from this area to doff the PCPUs and combat boots. The coveralls were carefully removed in the changing room, and placed well away from the contamination area.

Post-simulation Perceived Hazard Questionnaire. After completing the simulated decontamination, subjects filled out a brief questionnaire on their perceptions of hazard associated with the procedure (see Appendix B). Each instructional step of the procedure was rated from 1 to 7 on how safe or hazardous it was perceived to be for the subject in the passive role, i.e., the soldier being deconned. The questionnaire did not include Steps 2 and 14, which did not affect the subject in the passive role, or the conceptual Step 13 ("Switch roles").

Debriefing. During debriefing, subjects were informed that what they experienced in this study did not necessarily reflect either the actual field characteristics of live chemical agents or the nature of any protective garments or decontamination procedures that they might utilize in the future.

Post-simulation examination of coveralls. As soon as the subjects were dismissed, the coveralls were examined for tracer contamination, which was measured and graphically recorded in the same manner as during the simulation.

Analysis strategy. Contamination data were obtained in three ways: 1) observation of tracer agent on the coverall or socks made while examining the subject during a pause in the simulation; 2) contact of a contaminative nature observed during the ongoing simulation involving areas other than the coverall or socks (e.g., touching a contaminated surface with the hand or foot); and 3) tracer observed on the coverall after the simulation was over, and which had not been noted during the simulation. Data obtained by method 3 were not always identifiable with a particular procedural step or attributable to a particular cause.

For methods 1 and 3, tracer stains on the coveralls or socks were quantified both as locus numerosity and as total cm^2; the intended use of the latter was to derive the percentage of contaminated dermal area relative to total dermal area of the subject.

For method 2, contaminative contact was categorized as either dermal or nondermal. Dermal includes the coverall "skin," the actual skin, and the socks; contamination of these areas would directly produce casualties. "Nondermal" contamination means, in effect, contamination of the outer surface of the combat boot, the negative consequences of which would probably be delayed and

possibly averted. For nondermal data, the number of contact events was available, and often the number of loci; the dermal percent could be estimated for some cases.

For some of the contamination events from all three routes the only data are the number of contacts; in these cases it was presumed that there was a single locus, and that its extent is not obtainable. It is likely that many of these cases, if quantifiable, would be of minute area. Since any one of the dependent variables used to measure contamination may have failed to detect some contamination, the data as a whole should be considered conservative.

The strategy for analyzing the data was to compare the different procedural steps or substeps in the hasty decon instructions. There are 25 steps in all. Step 13 ("Switch roles") was not included in any of the analyses, because it was not an active process. Steps 2 and 4, which both consist of the active member of the pair decontaminating his/her own gloves, were not included in analyses of the Perceived Hazard Rating, since they did not directly affect the safety of the soldier being deconned.

Dependent measures were Time, Perceived Hazard Rating, and six measures of contamination. Multiple contamination metrics (which are highly correlated with each other) were analyzed simply to determine the most useful dependent measures for this type of study. The contamination measures consist of the following: the total number of contamination events (both dermal and nondermal), the total number of contamination loci (both dermal and nondermal), the number of dermal contamination events, the number of loci of dermal contamination, the number of nondermal contamination events, and the number of loci of nondermal contamination.

All analyses were conducted with the Statistical Analysis System (SAS) Version 6.06. Analyses of Variance (ANOVA) and Covariance (ANCOVA) were performed using Procedural Step as a categorical variable. A potential confound was the effect of decontamination order within a pair of subjects: after the first member of a pair was deconned, learning may have taken place on the part of both subjects such that the second decon may have been performed differently. Where main effects were found for Within-Pair Order, the analysis was redone using the order as a covariate. Hence the model used the independent variables Procedural Step and Within-Pair Order to predict the following eight dependent measures: Nondermal Events, Nondermal Loci, Dermal Events, Dermal Loci, Total Events, Total Loci, Time, and Perceived Hazard Rating.

Results

Contamination Data

None of the subjects completed the simulation free of dermal contamination. Table 2 shows mean values of the six contamination measures for each procedural step. The effect of Step is significant for five of them: Nondermal Events, $F(22, 253) = 1.78$, $p < .0194$; Dermal Events, $F(22, 253) = 1.9$, $p < .0105$; Dermal Loci, $F(22,253) = 2.29$, $p < .0012$; Total Events, $F(22,253) = 2.05$, $p < .0047$; and Total Loci, $F(22,253) = 2.25$, $p < .0015$. The R^2 values of Step for these measures are .13, .14, .17, .15, and .16, respectively. In post-hoc analyses, Fisher's LSD revealed that four of these measures identified steps which produced significantly high contamination levels. These steps are 5a ("Roll buddy's BDU trouser legs"), 9b ("Buddy removes combat boots"), 10 ("Buddy removes lower PCPU"), and 12c ("Buddy dons new overboots").

No significant main effects were produced by Within-Pair Order upon any of the contamination variables. The interaction between Step and Within-Pair Order was significant for Nondermal Events, $F(22, 230) = 2.03$, $p < .0055$, Nondermal Loci, $F(22, 230) = 1.81$, $p < .0174$, Dermal Events, $F(22, 230) = 2.32$, $p < .0011$, and Total Events, $F(22, 230) = 1.84$, $p < .0148$. The steps in which Within-Pair Order affected contamination were: Step 5b ("Decon buddy's overboots") for Dermal Events, $t(10) = 2.2361$, $p < .0493$, and Step 10 ("Buddy doffs lower PCPU") for both Dermal and Total Events, $t(10) = 3.1305$, $p < .0107$. In addition, borderline significance was found for the effect of Within-Pair Order on Dermal Events ($p = .08$) in Step 5a ("Roll buddy's BDU pant legs"), Dermal ($p = .07$) and Total ($p = .06$) Events in Step 7 ("Buddy doffs gloves"), and Nondermal Events ($p = .06$) in Step 12c ("Buddy dons overboots").

The steps were differentially prone to dermal or nondermal contamination. Figure 2 shows mean Total Events broken down by contamination type. Contamination data for individual subjects are provided in Appendix C, Tables C-1 through C-6. The somatic maps in Appendix D indicate the loci of contamination for each step, across all subjects; Appendix E includes maps for each subject indicating the loci of contamination across all steps.

The initial plan to measure dermal contamination as a percentage of body surface was not utilized. This was because an unexpectedly large proportion of the dermal contacts were recorded by observation during the simulation rather than by examination of tracer stains after the simulation was concluded, and in many cases these dermal contacts were much larger in area than the coverall traces. For example, one subject brushed his hand against his partner's contaminated hood: there was clearly a sizeable area of contact, but exactly how much was not determinable. Any calculations of contamination as dermal percent from measurable

Table 2. Mean (N = 12) Values on Contamination Measures

	Contaminative Contacts					
	Nondermal		Dermal		Total	
Step	Events *	Loci	Events *	Loci **	Events **	Loci **
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4a	0	0	0.08	0.08	0.08	0.08
4b	0	0	0.17	0.17	0.17	0.17
4c	0	0	0	0	0	0
4d	0	0	0.08	0.08	0.08	0.08
5a	0.08	0.17	0.50 ←	0.50	0.58	0.67
5b	0.17	0.17	0.25	0.33	0.42	0.50
5c	0.08	0.08	0.25	0.67	0.33	0.75
6	0	0	0.08	0.08	0.08	0.08
7	0	0	0.25	0.42	0.25	0.42
8	0.08	0.08	0.33	0.42	0.42	0.50
9a	0	0	0.25	0.42	0.25	0.42
9b	0.08	0.17	0.50 ←	0.75	0.58	0.92 ←
9c	0	0	0.17	0.25	0.17	0.25
10	0	0	0.75 ←	1.58 ←	0.75	1.58 ←
11a	0.08	0.08	0.33	0.42	0.42	0.50
11b	0	0	0.17	0.33	0.17	0.33
11c	0	0	0.08	0.08	0.08	0.08
12a	0.08	0.17	0.33	0.67	0.42	0.83
12b	0.17	0.25	0.08	0.08	0.25	0.33
12c	0.42 ←	0.58	0.17	0.17	0.58	0.75
13 †	--	--	--	--	--	--
14	0	0	0	0	0	0

* Effect of Step was significant at .05 level.

** Effect of Step was significant at .01 level.

← Denotes significantly high unique value or t-group via Fischer's LSD.

† Not an active process.

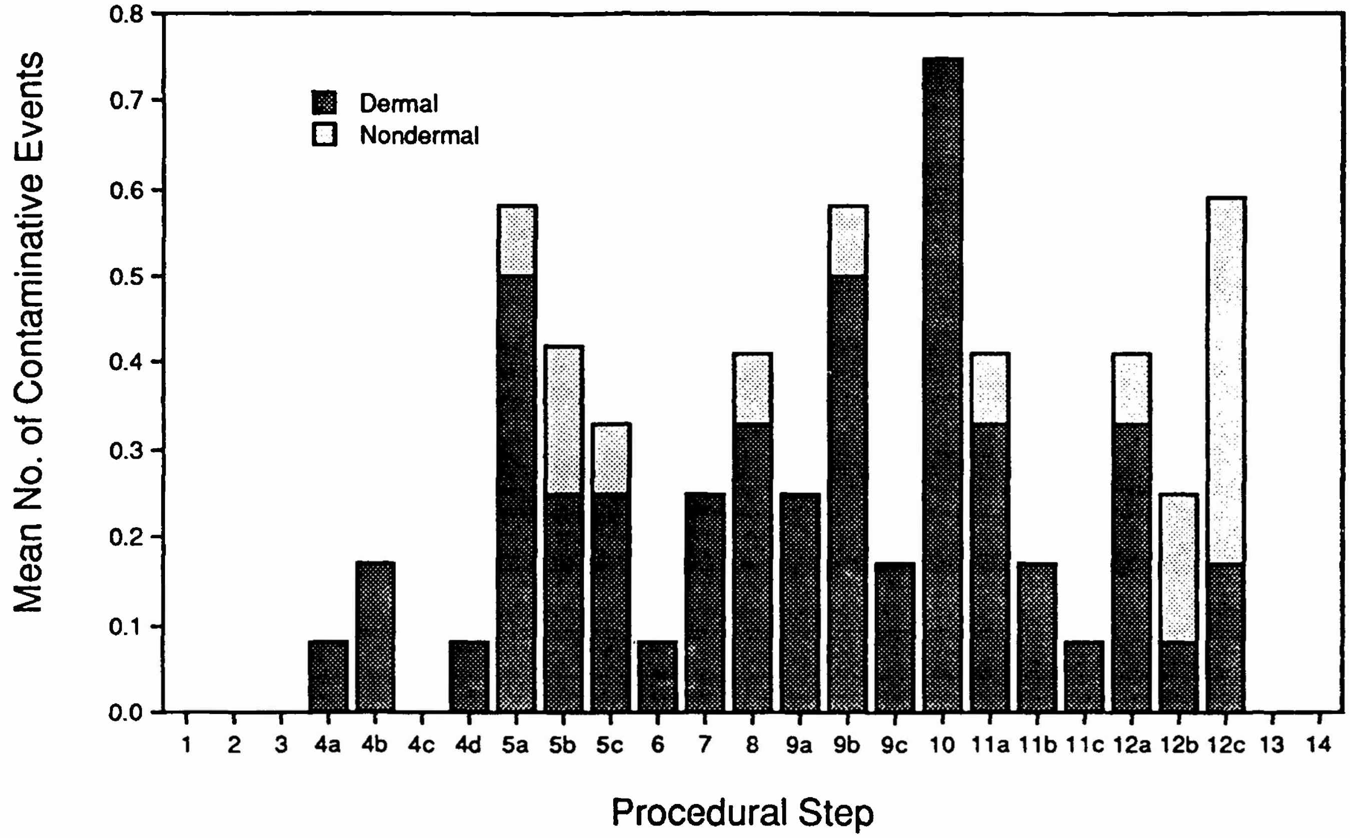


Figure 2. Mean total events (dermal and nondermal contaminations) within procedural steps.

contaminations would have been incomplete, and any estimations of unmeasurable contaminations would have been inaccurate. Hence no attempt was made to evaluate the contamination data in terms of the extent of the affected area or the volume of simulant acquired.

Probabilistic assessment. All of the subjects became "casualties" in the hasty decon simulation; none remained free of dermal contamination. It is not the purpose of this paper to speculate as to the effects of nonlethal doses of the less toxic agents, or the eventual consequences of nondermal contamination unbeknownst to the recipient. Similarly, these analyses ignore the fact that if the first soldier undergoing decon became a casualty, this fact would likely jeopardize the safety of the second soldier. The prescriptive assumption in the analyses of the contamination data is that contamination is dichotomous; any occurrence of it at all is seen as a failure of the hasty decon execution. In that sense, an event frequency approach to probability would suggest that the PCPU cannot be replaced in a hasty decon.

Such an event frequency approach is not optimal, however: the fact that within-step contamination was not measured as dichotomous allows finer predictions. In the different steps of the decon, there were various ways in which contamination occurred, various events that either did or did not take place. Theoretically there are an infinite number of such events, the majority of which did not occur. Since these nonevents are not addressable, the only conclusion is that whatever did happen, can happen. Nor is it determinable whether particular contaminative events are independent or exclusive. Hence the potential for contamination is defined on the basis of what was observed, ranging from nothing (or the minimum that occurred) to the maximum number of contamination events observed for that step. Therefore, the probability of contamination associated with a step is its mean Total Events divided by its maximum recorded value of Total Events. In this way, each step has its own distinct probability. From these can be derived the cumulative probability for the entire decon (unlike the frequency approach, which simply places the odds at unity since contamination occurred at some point in 12/12 cases).

Contamination probabilities are given in Table 3. The Discrete value is the chance of contamination occurring during the step itself; the Cumulative value is the chance that contamination will have taken place (at some point) by the end of that step. For example, of individuals undergoing Step 6, only 8% will become contaminated during that step, but almost 75% of cases will not have survived to reach Step 6. The last column illustrates this fact with an extrapolated survival rate. Note that, although the greatest numeric losses take place early in the decon, the hazards in the later steps are masked by the proportions: if the early losses could be avoided, the survivors would be subject to comparable attrition in the later steps. This is further illustrated by Figure 3, in which both the Discrete and Cumulative

Table 3. Probabilistic Assessment of Contamination in PCPU Hasty Decon

Step	Probability of Contamination		Survival per thousand
	Discrete†	Cumulative§	
1	.000	.0000000	1000
2	.000	.0000000	1000
3	.000	.0000000	1000
4a	.080	.0800000	920
4b	.170	.2364000	764
4c	.000	.2364000	764
4d	.080	.2974880	703
5a	.290	.5012165	499
5b	.420	.7107055	289
5c	.110	.7425279	257
6	.080	.7631257	237
7	.250	.8223443	178
8	.210	.8596519	140
9a	.125	.8771954	123
9b	.290	.9128088	87
9c	.170	.9276312	72
10	.375	.9547696	45
11a	.210	.9642680	36
11b	.170	.9703424	30
11c	.080	.9727150	27
12a	.420	.9841748	16
12b	.250	.9881311	12
12c	.290	.9915731	8
13	.000	.9915731	8
14	.000	.9915731	8

† The probability of contamination occurring in a step is

$$\frac{\text{(mean Total Events)}}{\text{(maximum observed Total Events)}}.$$

§ The cumulative probability of contamination, $p^c(C)_S$, of a step is defined recursively as:

$$p(C)_S\ (1 - p^c(C)_{S-1}) + p^c(C)_{S-1}$$

where S is an index of Step, and $p^c(C)_0$ is a dummy argument of zero.

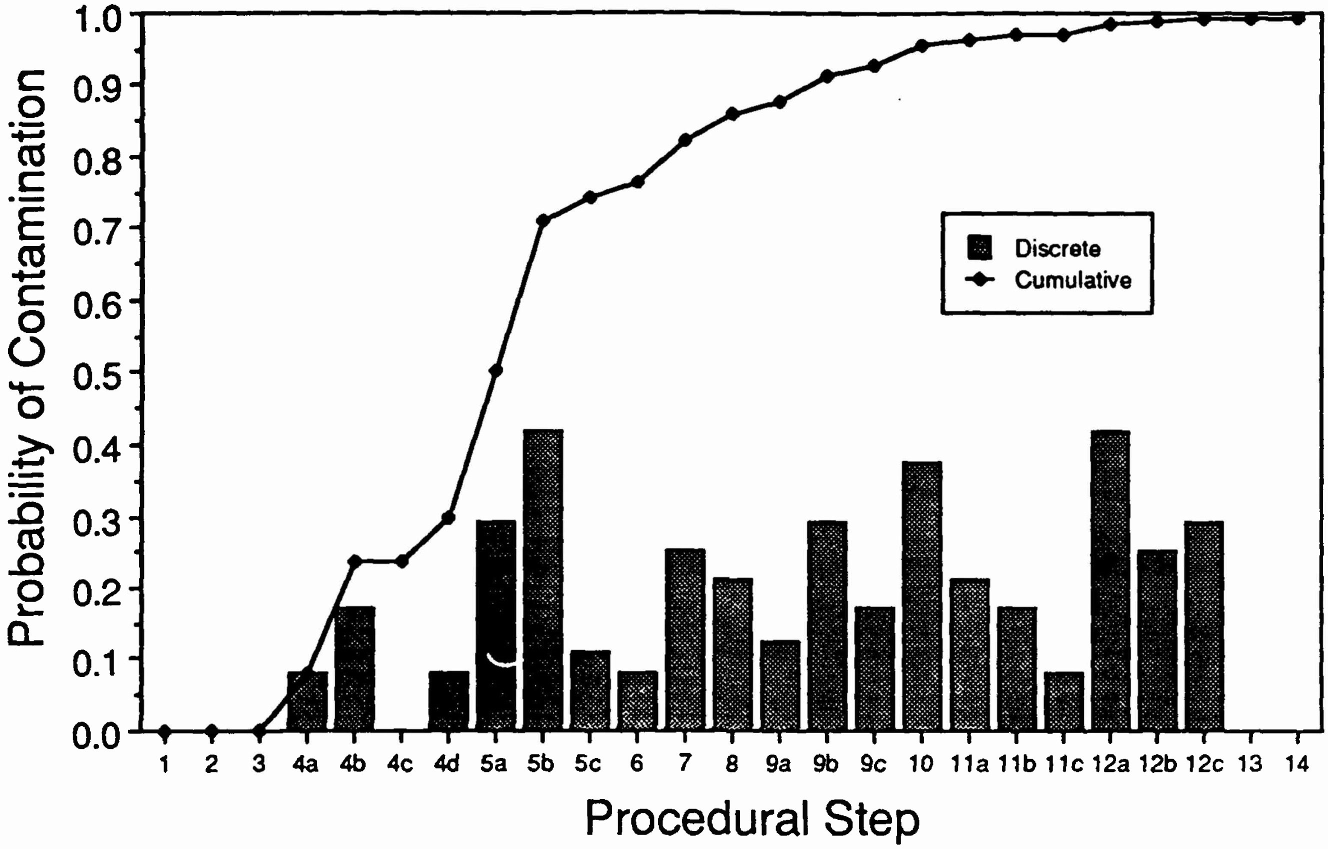


Figure 3. Probability of contamination during PCPU hasty decon steps, for discrete (bars) and cumulative (plot) occurrences.

probabilities are graphed concurrently: if the early discrete probabilities (bars) were decreased, the cumulative plot would increase more slowly, but the asymptote would be of comparable magnitude due to the high discrete values occurring later.

Time

The decontamination of one individual took approximately 20-24 minutes. The mean duration of each step is illustrated in Figure 4; the data are broken down by Within-Pair Order in Table 4. Step 13 was a conceptual step allowing for reversing roles; hence it was not timed and is not included in any analyses. Step 14 was executed only during the second decon within the pair, and is of interest only in terms of the total time taken by two soldiers to complete the hasty decon.

A main effect for Within-Pair-Order was found for Time, $F(1, 230) = 6.32$, $p < .0126$. The effect of Within-Pair Order upon Time is significant at .05 for Steps 2 ("Decon your own gloves") and 4b ("Buddy turns down BDU trousers"), both of which had greater mean values for the first decon. Using Within-Pair Order as a covariate, a significant main effect was found for Step upon Time, $F(30, 252) = 30.72$, $p < .0001$. None of the contamination variables is substantially correlated (i.e., $r > .2$) with Time.

Perceived Hazard Rating

Results of the questionnaire on subjective perception of hazard are given in Table 5. A main effect for Within-Pair-Order was found for Rating, $F(1, 230) = 4.01$, $p < .0463$. The only step which showed a significant effect of role was Step 3 ("Decon buddy's mask"). Ratings separated by within-pair order are given in Table 6. Individual response data are given in Appendix G.

Within-Pair Order was held as a covariate in a GLM analysis of Step upon Perceived Hazard Rating, $F(22, 252) = 5.19$, $p < .0001$. Post-hoc comparisons do not reveal any individual steps to be perceived as particularly hazardous, but a distinction can be made between the eight highest-rated steps and the rest (see Table 5). These are 4b ("Pull back buddy's hood"), 4c ("Remove buddy's PCPU top"), 6 ("Buddy turns down BDU trousers"), 8 ("Buddy everts lower PCPU waist"), 9a ("Buddy sits on safe zone"), 9b ("Buddy removes combat boots"), 9c ("Buddy adjusts bootlaces"), and 10 ("Buddy removes lower PCPU").

No substantial correlation exists between Perceived Hazard Rating and Time. The rating is not substantially correlated (i.e., $r > .2$) with the contamination of the buddy, nor with the within-pair sums of any of the contamination measures. However, for most of the step executions, the contamination values were zero. When the analysis includes only those cases in which subjects rated a step that produced contamination in their pair, the relationships

Table 4. Execution Times (in Minutes and Seconds) of PCPU Hasty Decon Procedural Steps

Step	Mean All Decons ($\underline{N}$ = 12)	Mean 1st Decon ($\underline{N}$ = 6)	Mean 2nd Decon ($\underline{N}$ = 6)	Difference 1st - 2nd ($\underline{N}$ = 6)
1	0:41.73	0:46.29	0:37.17	0:09.12
2	0:54.10	1:11.64	0:36.57	0:35.07 *
3	1:49.97 c	1:45.54	1:54.40	-0:08.85
4a	0:35.74	0:38.91	0:32.58	0:06.33
4b	0:25.55	0:32.94	0:18.17	0:14.78 *
4c	0:31.23	0:31.82	0:30.64	0:01.18
4d	0:16.19	0:18.72	0:13.66	0:05.06
5a	1:43.79 c	1:50.21	1:37.36	0:12.85
5b	1:02.63	1:15.01	0:50.25	0:24.76
5c	0:50.38	0:51.14	0:49.62	0:01.52
6	0:12.29	0:13.07	0:11.51	0:01.56
7	0:19.84	0:21.03	0:18.66	0:02.37
8	0:19.09	0:18.23	0:19.95	-0:01.71
9a	0:10.82	0:11.87	0:09.76	0:02.11
9b	1:04.53	1:10.95	0:58.12	0:12.83
9c	0:08.26	0:13.86	0:02.66	0:11.20
10	1:04.78	1:11.83	0:57.72	0:14.11
11a	0:41.23	0:45.37	0:37.08	0:08.29
11b	0:49.18	0:47.51	0:50.86	-0:03.35
11c	1:08.16	1:06.10	1:10.23	-0:04.12
12a	3:28.29 a	3:47.80	3:08.78	0:39.02
12b	1:41.27 c	1:33.99	1:48.55	-0:14.56
12c	2:25.26 b	2:47.27	2:03.26	0:44.01
13	--	--	--	--
14	--	--	0:24.80	--
Total	22:24.30 (SD 5:03.97)	24:11.09 (SD 3:40.10)	20:37.52 † (SD 2:44.78)	3:33.57
	Per Pair ($\underline{N}$ = 6)			
	45:13.40 § (SD 5:03.98)	--	--	--

* Significant at .05 level.

abc Letter codes denote significantly high unique value or $\underline{t}$-group via Fischer's LSD.

† Exclusive of Step 14.

§ Inclusive of Step 14.

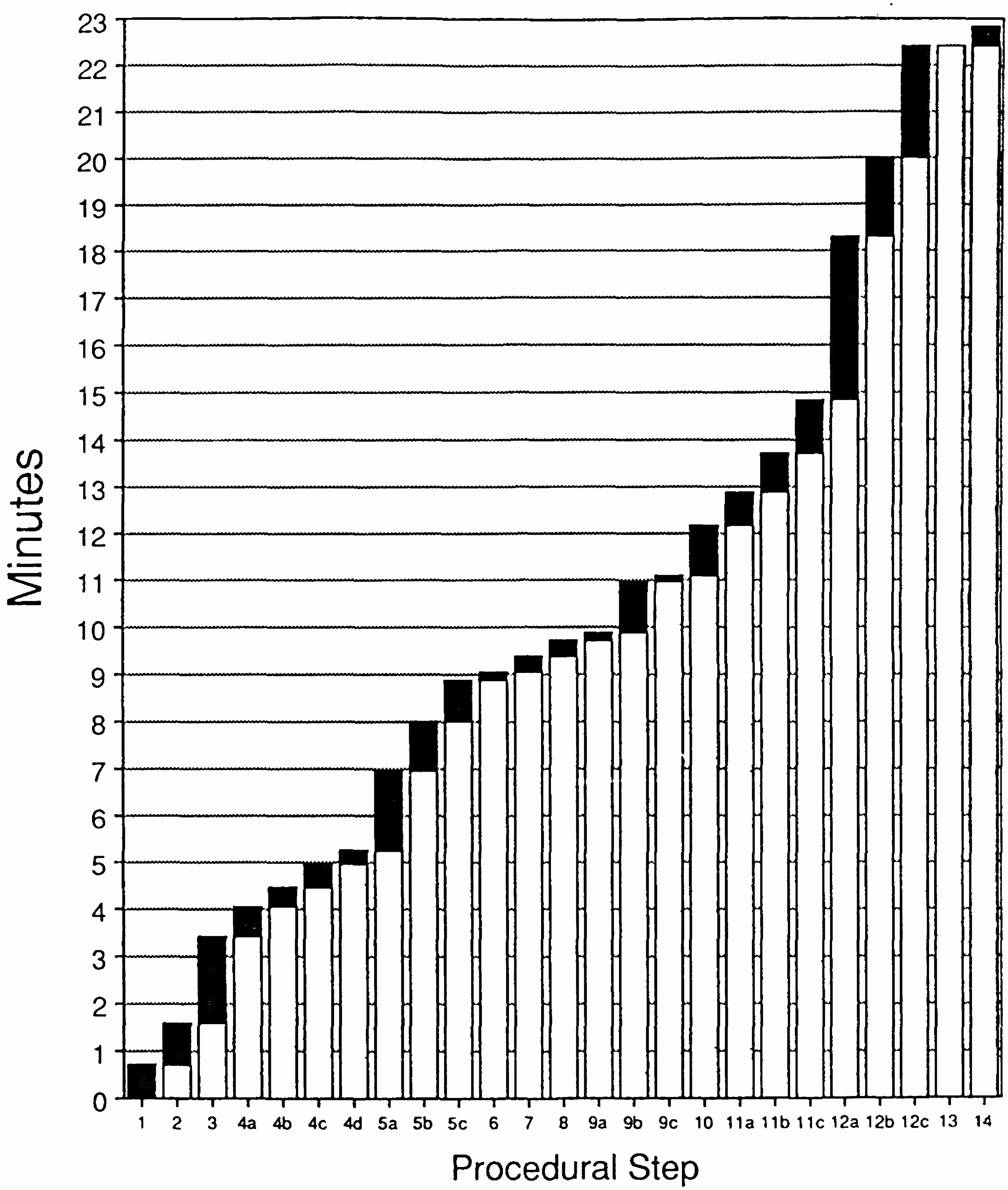


Figure 4. Time data of the procedural steps of the PCPU hasty decon ($\underline{N}$ = 12). The shaded portion of each bar represents the individual step duration; the white portion represents the cumulative duration of all previous steps. No time was recorded for Step 13 ("Switch roles"). Step 14 (final glove decon) was performed only by one member of each pair (hence $\underline{N}$ = 6 for that step).

Table 5. Perceived Hazard Questionnaire Ratings of the PCPU Hasty Decon Procedural Steps

		Perceived Hazard Rating[1] ($\underline{N}$ = 12)								
		Value		Plot of Means[2]						
Step		Mean	SD	1	2	3	4	5	6	7
1	Remove BDU coat	2.08	1.31	·	B	·	·	·	·	·
2	Decon own gloves	†	†	·	·	·	·	·	·	·
3	Decon mask	2.33	1.92	·	·B	·	·	·	·	·
4a	B. everts pants	3.17	1.40	·	·	B	·	·	·	·
4b	Pull off hood	3.83	1.85	·	·	·	A·	·	·	·
4c	Remove CP top	4.00	1.95	·	·	·	A	·	·	·
4d	Spread CP top	3.50	1.78	·	·	· B	·	·	·	·
5a	Roll pant legs	3.58	1.88	·	·	· B	·	·	·	·
5b	Decon overboots	2.17	1.03	·	B	·	·	·	·	·
5c	Remove overboots	2.75	1.54	·	·	B·	·	·	·	·
6	Roll BDU pants	4.00	1.80	·	·	·	A	·	·	·
7	B. doffs gloves	2.83	1.58	·	·	B·	·	·	·	·
8	B. everts lower PCPU	4.83	1.33	·	·	·	·	A·	·	·
9a	B. sits	4.92	1.56	·	·	·	·	A	·	·
9b	B. doffs boots	4.58	1.50	·	·	·	· A	·	·	·
9c	B. adjusts laces	3.67	1.77	·	·	· A	·	·	·	·
10	B. doffs lower PCPU	3.83	1.74	·	·	·	A·	·	·	·
11a	B. dons lower PCPU	2.92	1.62	·	·	B	·	·	·	·
11b	B. dons top PCPU	2.83	1.57	·	·	B·	·	·	·	·
11c	B. dons gloves	2.75	1.60	·	·	B·	·	·	·	·
12a	B. dons BDUs	2.50	1.78	·	· B	·	·	·	·	·
12b	B. dons combat boots	2.83	1.89	·	·	B·	·	·	·	·
12c	B. dons overboots	2.67	1.87	·	· B	·	·	·	·	·
13	Switch roles	§	§							
14	Decon own gloves	†	†							

1 Scale: 1 = "SAFE", 7 = "HAZARDOUS".

2 Letters signify distinct LSD $\underline{t}$-group (threshold = 3.625).

† Not included on the questionnaire because it did not affect the passive subject's safety.

§ Not included on the questionnaire because it was not an active process.

Table 6. Perceived Hazard Ratings and Within-Pair Order

Step	Mean Rating 1st Decon (N = 6)	Mean Rating 2nd Decon (N = 6)	Difference 1st - 2nd (N = 6)
1	1.83	2.33	-0.50
2	†	†	†
3	1.17	3.50	-2.33 *
4a	2.83	3.50	-0.67
4b	3.17	4.50	-1.33
4c	3.83	4.17	-0.33
4d	3.00	4.00	-1.00
5a	3.83	3.33	0.50
5b	1.83	2.50	-0.67
5c	2.67	2.83	-0.17
6	4.17	3.83	0.33
7	2.83	2.83	0.00
8	5.17	4.50	0.67
9a	5.17	4.67	0.50
9b	4.50	4.67	-0.17
9c	2.83	4.50	-1.67
10	3.83	3.83	0.00
11a	2.67	3.17	-0.50
11b	2.67	3.00	-0.33
11c	2.83	2.67	0.17
12a	2.33	2.67	-0.33
12b	2.50	3.17	-0.67
12c	2.33	3.00	-0.60
13	†	†	†
14	†	†	†

† Not included in questionnaire.

* Significant at .05 level.

are somewhat greater: Perceived Hazard Rating was correlated at +.35 with the within-pair sum of Dermal Events, and at approximately +.30 with the buddy's Dermal Loci and Total Loci, and with the within-pair sums of Dermal Loci, Total Events, and Total Loci.

Discussion

Problematic Steps in the PCPU Hasty Decon

The above analyses reveal that 14 of the steps in the hasty decon procedure are salient in some way; these results are organized in Table 7. The possible problems with each of these steps will be examined in turn. Distinctions include some borderline effects that will be noted as such. The specific routes whereby contamination occurred for all steps are provided in detail in Table 8 and are condensed in Table 9.

Table 7. Summary of Problematic Steps in the Hasty Decon Procedure

Source of Concern	Affected Steps													
High Contamination †				5a	5b					9b		10	12a	12c
High Perceived Hazard		4b	4c			6		8	9a	9b	9c	10		
Order Affects Contamination				5a	5b		7					10		12c
Order Affects Step Duration	2	4b												

† Significantly high contamination values (from Table 2), with the exception of Steps 12a and 5b, which have a high contamination probability (see Table 3).

Step 2 ("Decon your own gloves"). This has significantly different durations between the two decons within a pair; it is longer in the first pass. No explanation is apparent, other than that the subjects may have been uncertain of the behavior of the tracer agent early in the simulation, and adjusted their actions with experience. It is also possible that subjects accelerated the procedure to finish sooner. Since this step is irrelevant to the primary issue of the study (doffing a PCPU), this differential duration is of no real concern.

Step 4b ("Pull off buddy's PCPU hood"). This step is distinct in two ways. It took significantly longer in the first decon, a result probably due either to expeditiousness and/or learning.

It also has a significantly high Perceived Hazard rating, although it does not have a comparably high contamination probability. The danger of contaminating the buddy's forehead in this step was probably obvious enough to the subjects to make them appropriately careful in executing it.

These distinctions are not problematic for the feasibility of the PCPU hasty decon.

Table 8. Sources of Contamination Within Step, by Frequency

Procedural Step	Source and Number of Contaminations
1 Remove BDU coat	none
2 Decon own gloves	none
3 Decon mask	none
4a B. everts pants	contact with partner (1)
4b Pull off hood	contact with partner (2)
4c Remove CP top	none
4d Spread CP top	partner touches lining (1)
5a Roll pant legs	contact with partner (3), self-contact (2), contaminated BDU ties touch combat boots (1), unknown (1)
5b Decon overboots	combat boots contaminated (2), contact with partner (2), self-contact (1)
5c Remove overboots	self-contact (1), combat boots contaminated (1), contaminated mask touches sternum (1), BDU ties contaminate calves (1)
6 Roll BDU pants	arm contact with partner (1)
7 B. doffs gloves	hand contacts glove exterior (3)
8 B. lowers PCPU	hands touch PCPU exterior (2), steps off safe zone (2), outer waistband contacts calf (1)
9a B. sits	hand touches PCPU cuff (1), contaminated BDU ties touch ankle (1), hand on ground (1)
9b B. doffs boots	hands touch exposed PCPU/BDU exterior (6), sits/steps off safe zone (2), contaminated mask touches knees (1)
9c B. adjusts laces	combat boot laces touch ground & sternum (1), combat boot laces touch ground & fingers (1)
10 B. doffs lower PCPU	PCPU cuffs touch ankles/feet (3), sits/places feet off safe zone (2), hands touch exposed PCPU/BDU exterior (2), contaminated mask touches knee (1), contact with partner (1)
11a B. dons lower PCPU	feet on ground (2), PCPU cuff touches ground & ankle (1), combat boot touches ground (1), unknown (1)
11b B. dons top PCPU	steps off safe zone (1), hand touches contaminated mask (1)
11c B. dons gloves	stands off safe zone (1), unknown (1)
12a B. dons BDUs	foot/ankle contaminated by BDU ties dragged on ground (2), combat boots contaminated by BDU ties (2)

(continued)

Table 8 continued

Procedural Step	Source and Number of Contaminations
12b B. dons combat bts.	combat boot laces drag on ground & touched (2), unknown (1)
12c B. dons overboots	combat boots contaminated from ground (2), combat boots contaminated from overboot laces dragged on ground (2), contaminated overboot interior touches combat boots (2), gloved hand touches ground & combat boots (1)

Table 9. Summary of the Causes of Contamination Events

Number	Category	%	Histogram
16	Item touches ground	21.6	
13	Faulty doffing	17.5	
11	Moves off safe zone	14.8	
10	Contact with partner	13.5	
9	Passive self-contact*	12.1	
6	Other or Unknown	8.1	
5	Tracer on combat boot	6.7	
4	Active self-contact*	5.4	
74	All		

* "Passive" self-contact refers to incidental contacts that were not part of an active process and which the subject may not have been aware of; e.g., while standing, the forearm touches the waistband of the lower PCPU. "Active" self-contacts occurred during committed actions, e.g., touching the PCPU cuff with the hands while removing combat boots. This distinction is made because requisite corrective training would differ between the two.

Step 4c ("Remove buddy's PCPU top"). This step has a significantly high Perceived Hazard rating (but is not significantly highly prone to contamination). There are many ways in which this step can go wrong, either by directly contaminating the buddy or by making him or her rely on an unsafe "safe zone." In effect, the subjects' perceptions are warranted. Since this step is functionally similar to the standard MOPP4 gear exchange and is not associated with significantly high contamination, the high rating is not problematic for the feasibility of the PCPU hasty decon.

Step 5a ("Roll buddy's BDU trouser legs"). This step has a significantly high level of Dermal Events. Examination of the data reveals that the contributing events are contacts with the active partner, whc is bent over concentrating on the buddy's legs; the passive buddy typically lets his or her arms hang too low, and the active partner stands unexpectedly, causing contamination of the buddy's hand or arm. The active partner is often behind the buddy's back during this step, and moves forward without looking up to see that the buddy's arms are clear. Although subjects were instructed during the initial donning to blouse their BDU trousers more loosely than usual in order to facilitate tugging them out of the still-laced combat boots, some subjects had difficulty unblousing them. In one case, the pair made no progress and received assistance from the experimenter. They were instructed to assume that they had cut/torn the garment in order to proceed.

There is a borderline effect of Within-Pair Order upon Dermal Events which, if verified, could be attributable to learning: when contamination of this sort occurs at this step in the first decon, the pair may be more careful when reaching this step in the second decon. Such an effect, if found, would not be a concern.

The dangers of this step are not reflected by the Perceived Hazard ratings; subjects may not have realized the hazards. Since the high contamination level associated with this step is attributable to carelessness, it can probably be reduced with training and a more cautionary step instruction. Hence this step is not ultimately problematic for the PCPU hasty decon.

Step 5b ("Decon buddy's overboots"). There is a significant effect of Within-Pair Order on Dermal Events in this step, which is probably due to learning, as in Step 5a. This step also has a high contamination probability (.42 from Table 3), largely from inefficient execution leading to contaminated combat boots or to accidental intersubject contact. These problems are likely reducible with training. This step is not problematic for the PCPU hasty decon.

Step 6 ("Roll BDU pants for removal"). This step has a significantly high Perceived Hazard rating. This step is similar to Step 5a, and subjects may have mistakenly attributed the conta-

mination from Step 5a to Step 6. It is also possible that, if they were aware of contamination in Step 5a, their awareness of potential hazards may have made them careful in Step 6. This would explain its high rating and lack of high contamination. Step 6 is not problematical for the hasty decon of PCPUs.

Step 7 ("Buddy removes gloves"). Borderline significance was found for the effect of Within-Pair Order on Dermal events and on Total Events. A significant effect, if found, would be difficult to explain, but would not be problematical.

Step 8 ("Buddy turns down lower PCPU"). This step has a significantly high Perceived Hazard rating. Since this step has obvious hazards and did not have accompanying high contamination levels, the high rating probably reflects an accurate perception that functioned in a self-cautionary manner. Hence the high rating is not of concern.

Step 9a ("Buddy sits on safe zone"). This step has a significantly high Perceived Hazard rating. This step has many obvious hazards but did not have significantly high contamination levels, hence the rating probably reflects an accurate perception that functioned in a self-cautionary manner. Nocturnal execution of this step might be substantially more hazardous, but since the step is similar to that of the MOPP4 exchange, it cannot be said to be a concern for the feasibility of PCPU hasty decon.

Step 9b ("Buddy removes combat boots"). This has significantly high levels of Dermal Events and Total Loci, and a significantly high Perceived Hazard Rating. Contamination occurred primarily in two ways: touching the wrists or forearms with the exposed outer surface of the lower PCPU cuffs, and dragging the bootlaces across contaminated terrain outside the safe zone and then handling them. This step is particularly awkward, difficult to perform, and fraught with potential hazards, including losing balance and falling off the safe zone. Visibility of the feet is impaired by the bodily position, and if the mask has not been properly deconned (in Step 3) its lower parts can contaminate the knees and lower thighs. Since the perimeter of the safe zone must be determined by sight, not touch, and since the movements of the bootlaces must be kept track of, it is likely that reduced light conditions would severely increase the danger of this step. The high Perceived Hazard rating is an accurate perception and needs no explanation.

This step is an essential part of the PCPU hasty decon, and takes the form that it does as a direct consequence of the nature of the PCPU garment set. The problems associated with this step are critical shortcomings of the PCPU hasty decon.

Step 9c ("Buddy adjusts bootlaces"). This has a significantly high Perceived Hazard rating, which is difficult to interpret,

given that contamination levels are not significantly high. It may be a perception of the potential for indirect contamination via the laces touching the ground in Step 9b. If so, the potential is not of concern provided that Step 9a was executed properly.

It appears that the perception of hazard associated with this step is misdirected. Some of the subjects voiced comments to the effect that they felt vulnerable during the hasty decon and would forego superfluous neatness for the sake of becoming protected sooner. Most of these comments centered upon skipping some shirt buttons, but at least two individuals suggested expeditiously wrapping the bootlaces around the boot shaft as being a satisfactory shortcut. One individual noticed that his lace aglet touched the contaminated ground in Step 12b ("Redon combat boots"). He was instructed that, in reality, he would ask his partner to cut off a few inches of the lace.

Step 10 ("Buddy removes lower PCPU"). This step has significantly high contamination values on Dermal Events, Dermal Loci, and Total Loci; and has a high contamination probability (.375 from Table 3). It also shows a significant effect of Within-Pair Order on Dermal Events and Total Events. On four of the six contamination measures, the highest values were found in this step. Most of the contaminations were of the feet, ankles, and hands. The step is awkward and has a risk of placing the feet off of the safe zone. If executed properly, it is difficult for the buddy to see what may be happening around his or her ankles. If subjects' hands are contaminated unbeknownst to them, they risk spreading the agent onto extensive portions of their lower legs. Verbal guidance and advice from the active partner did not seem helpful. It is likely that nighttime execution of this step would be substantially more hazardous.

The effect of Within-Pair Order is probably the result of learning. The subjective hazard perception is accurate and warranted.

This step is a critical part of the PCPU hasty decon; in fact it is the keystone step necessitated by the nature of the PCPU garment set, predicated on the logistic assumptions made in the introduction. The success of this step hinges upon the stability of the bundled garments (BDU pants and lower PCPU); if the bundle is formed properly and remains stable, the step is much easier and safer. Although it is likely that some of the contamination from this step could be reduced with training, the behavior of the garment bundle may vary with the nature and thickness of the PCPU material. The sweatpants used as the prototype PCPU may have performed differently in this respect than would a functional product. The prior correct execution of Step 5a and Step 6 is essential for insuring the stability of the garment bundle in Step 10.

The conclusion is that this step is feasible but carries a high risk: with care it can be executed safely, but if executed poorly (or if previous contamination of the hands has occurred) the consequences can be severe.

Step 12a ("Buddy dons new BDUs"). This step had a high contamination probability (.42 from Table 3), due almost entirely from the drawstrings of the trouser-cuffs touching the ground and then the feet. Training would likely reduce this probability, hence this step is not a critical problem.

Step 12c ("Buddy dons new overboots"). This had a significantly high level of Nondermal Events, and a borderline effect of Within-Pair Order on Nondermal Events.

The majority of contaminations in this step were caused by the overboot laces dragging on the contaminated ground and then brushing across the combat boots. If this happened to the first overboot donned, then, when the laces were handled, contamination was sometimes spread to the inside of the other overboot and thus to the combat boot. Regardless of whether or not the agent penetrates the combat boot, it will be a hazard later when the soldier is inevitably deconned again. If it is another hasty decon, the boots can contaminate the safe zone or can contaminate the hands when doffing. If it is a more deliberate decon, the soldier may unknowingly convey the agent on his boots into a shelter or vehicle.

These concerns are aggravated by the fact that subjects did not perceive the associated hazard in this step; this is a subtle danger that went unnoticed. Training and cautionary instructions would likely reduce this hazard. In the simulation, the overboots were given to the subjects rolled up but already laced; the issuance of nonlaced overboots with accompanying instructions would likely reduce contamination in this step, as might the issuance of the laceless green vinyl overboots. This step is not a critical problem for PCPU hasty decon.

Comparison with Other Studies

The mean time of 22 minutes for completing a decon of one subject is comparable to that of Harrah et al.'s study of MOPP4, which had a mean of 23-24 minutes for 115 trials (Harrah et al., 1990, p 20). Contamination results are similar, in that subjects were not able to successfully complete the hasty decon. Harrah et al. found a greater effect of within-pair order upon contamination than did the present study.

Time data of Blewett et al.'s (1991) CPU study were shorter: approximately 15 minutes per individual on average (p 4). Contamination in that study occurred in only a single trial (out of 5), and was attributed to two events. Differences in contamination

results of that study from the present one may be attributable to differences in the garments and differences in methodology.

The garments differed in that 1) their CPU was form-fitting and sized in 2-inch increments, whereas the PCPU used in the present study was loose-fitting and sized in only "medium" and "large"; and 2) Blewett et al.'s CPU had no hood, whereas the PCPU upper garment had an integrated hood.

Methodological differences included 1) differences in the application of tracer and 2) the hasty decon procedures followed. Their tracer was applied at a concentration of 10 g/m^2 (p. 3), substantially less than the present study (approximately 200 g/m^2), and they did not reapply tracer onto the CPU after the outer nonprotective garments were removed, as was done in the present study. Blewett et al.'s procedure (p. 10-11) assumed the availability of replacement combat boots, and an additional large safe zone made by either turning the soil or spreading a poncho. These assumptions rendered their decontamination procedure less complicated than that used in the present study.

Interpretation and Recommendations

There are several ways that the potential for contamination can be reduced:

1) Training. The probability of contamination can be reduced with training in the steps where specific causes can be identified. Bear in mind that the steps that were not statistically singled out as problematical were nevertheless productive of contamination. It is reasonable to predict that training would improve general performance, and thus reduce contamination potentials overall, even where the specific sources are not methodically identifiable.

However, if some portion of the contamination potential is the result of a flawed procedure, then training in the flawed procedure will not avert the consequences. The assessment of problematic steps has identified flaws in the procedural instructions. Flaws in the instructions and some remedies are discussed next.

2) Modification of procedure and instructions. Based upon the results of this simulation, the instructions for performing Steps 5a, 9b, and 12c of the PCPU hasty decon have been augmented to emphasize precautionary measures.

Step 5a is now preceded by the caveat, "Instruct your buddy to hold his or her arms up, with elbows high, to keep from touching you."

Step 9b is modified to read, "Instruct your buddy to remove his or her combat boots, being careful that the laces do not touch the contaminated ground. Your buddy places each boot on an arm of the safe zone."

Step 12a adds the caveat to prevent the BDU trousers from touching the ground.

Step 12c is changed to, "Buddy extracts new CP overboots without touching the outside of package. Laces, if present, must not drag on ground. Your buddy dons the new overboots."

One additional change is made based not upon contamination data, but upon time data and rational consideration. This change is regards donning the new BDUs. Step 12a, in which the subjects donned the trousers and coat in one step, was lengthy (approx 3.5 min), largely due to the difficulty of manipulating buttons while gloved. The BDU trousers must be put on before the combat boots and overboots, but the BDU coat need not be donned at that time. While the subjects were laboring at the buttons of their BDU coats (which gave no protection), their feet remained unprotected, and they were vulnerably confined to the safe zone. This portion of the hasty decon procedure was defined with the assumption that concealment had a higher priority than the speed of restoring NBC protection. This assumption is presently seen as outside the domain of this study. In the revised procedure, the BDU coat is donned last, in a new Step 12d.

The revised PCPU hasty decon procedure (Appendix G) incorporates the changes from above plus some linguistic modifications and has encapsulating prescriptions to place it in a field context akin to that of the MOPP4 hasty decon of FM 3-5 (Department of the Army, 1985a).

Presuming that training with optimized instructions would reach an asymptote of contamination avoidance, any remaining potential for contamination would be either nonattributable randomness or physical shortcomings of the design of the PCPU and the way it is used.

<u>3) Modifications to PCPU form and use</u>. The steps in the PCPU hasty decon which are most problematic involve the removal of the lower garment. The manner in which it is removed is necessitated by the fact that it cannot be done without endangering the unprotected feet. If the feet were protected, or if the garment could be removed without endangering them, then two of the biggest contributors to the probability of contamination could be avoided. Removal without endangering the feet could be effected by procedural changes and/or design changes.

One procedural change would be to cut or tear the lower PCPU garment, which is generally not recommended, and which might create new hazards. Another would be to provide new combat boots along with the new PCPUs, gloves, overboots, and BDUs, albeit this further burdens the distributional logistics of implementing the PCPU.

A change in the way the garments are used within the NBC posture would be to supplement the ensemble with protective socks (presumably chemically adsorptive but possibly impermeable), which would be discarded and replaced in the hasty decon.

A simpler and more direct approach would be to supplement the lower PCPU garment with feet. The addition of attached feet would remove much of the hazard in doffing the lower PCPU (Step 10), both directly and by eliminating the logically related steps. It would also reduce the time requirements by letting the active party grasp his or her buddy's lower PCPU to aid in removing it.

The addition of feet would also be of benefit in Step 5a ("Roll up buddy's trouser legs"), by reducing both contamination potential and execution time. Step 5a could alternately benefit from stirrup straps to keep the PCPU legs from riding up. However, attached feet would be of greater utility, as stirrups would provide no direct protection nor could they be safely grasped by the buddy's partner in Step 10.

Although attached feet would benefit the hasty decon process, this design change would complicate sizing of the lower PCPU. For each garment size, there would have to be a number of sizes of attached feet if the wearer is to be properly shod and thus avoid foot problems, such as blisters, associated with poorly fitted footwear.

An alternative design change would allow the PCPU ankle cuffs to expand over the combat boots, and ideally over the overboots, by stretching, unzipping, or bellowing. This would eliminate the hazards caused by having the feet in an unshod state at the time of the lower PCPU removal.

Even a lesser degree of expansion of the ankle cuff, if combined with an overlong leg, might permit a preliminary protective procedure to Step 10: the ankle cuffs would be tugged down and then folded (not rolled) back, exposing the safe lining around the ankle and lower calf. This would reduce the hazard to the feet as the legs are withdrawn. The stability of the bundled PCPU and BDU pants, which is critical in this step, could be maintained via hook-and-pile fastenings on the waist and ankles of the lower PCPU. Such fastenings would have additional utility. On the ankle cuffs they could secure the blousing of a pleating or expansion feature. On the waist they would aid in customizing the fit.

Waist tabs would also help keep the waistband high: greater overlap of the two garments, produced by lengthening the upper one and/or raising the waist of the lower one, would remove some potential hazard in turning down the lower PCPU in Step 8. Complementarily situated fastenings on the hem of the upper garment could secure it to the lower garment to keep the two from

separating and creating a gap hazard, e.g., as in exposing the lower back when crouching.

Thus the addition of carefully situated hook-and-pile fasteners on the ankles of the lower of the two garments and on the waist of both could make the PCPU more efficient at protecting the wearer, as well as remove some hazard to the feet during the hasty decon.

The manner in which the PCPU-based posture is worn is also open to modification. Blousing the BDU trouser legs is questionable given the difficulty in removing them from laced combat boots. This study did not implement full saturation of garments with the simulant; it is possible that bloused BDUs may aggravate the spread of liquid agents into the combat boots. Spreading the BDU trouser cuffs over the outside of the overboots might help, but may not always be physically possible. The manner in which the PCPU ensemble was worn provided no "shingle" effect or overlap at the top of the combat boots. If the PCPU ankle cuffs were able to accommodate passage of the combat boots, as suggested earlier, then the cuffs could ipso facto be worn outside the shaft of the combat boot (and inside the overboot). The BDU cuffs would be of less concern in that case. Protective gaiters might easily solve the problem of runoff into the combat boot; these might well be redonned instead of discarded.

It is not apparent whether a unitary garment with a frontal zipper could be more safely doffed than the two-piece set, but the hazard of a gap in a two-piece set would thereby be eliminated.

Conclusions

The results of this study have been interpreted with the assumption that the simulation represented a worst-case or nearly worst-case scenario, in which the likelihood of failure was high and the definition of failure was broad. The subjects in this study did not practice the PCPU-based hasty decon procedure and, with one exception, had not observed the process. Furthermore, suspected contamination that spread inadvertently to dermal and to nondermal areas was not removed using a skin decon kit (in actuality it would be, and an antidote injected if needed before continuing), and it was assumed that any such contamination would ipso facto result in a casualty (which is not the case in actuality). Thus, this study was a very stringent assessment of the safety of a hasty decon protocol for the PCPU, the goal being to identify means for avoiding the hazard of contamination. The conclusions and associated recommendations of the assessment are as follows:

1. The PCPU-based posture used in this simulation study, and worn in the particular manner described, presents a high probability that contamination will occur when the hasty decon procedure is employed. Although the modifications made to the procedure and instructions can improve these odds, as can training in the procedure, there are remaining hazards which are a consequence of the design of the garments involved. The design modifications suggested supra could simultaneously a) eliminate these hazards by not generating them as design consequences, and b) decrease other hazards by functioning more efficiently with respect to the other elements of the protective posture.

2. The requisite logistic support of the PCPU hasty decon would at present be greater than that of the BDO; it would increase further if CP socks or gaiters are added. Since the time required for PCPU hasty decon is comparable to that for current MOPP gear, the use of a PCPU-based NBC posture gains no advantage over conventional CP attire in that respect. Thus this study finds that the PCPU-based posture fails to meet the policy prescriptives specified by Brigadier General Robert Orton, Commandant, US Army Chemical School, that "decon needs to get easier... less logistically burdensome...[and] faster" (Orton, 1990, p 29).

3. The primary design recommendation is the addition of attached feet to the lower PCPU garment. If this is not feasible, then it is recommended that ankle cuffs be wider and bloused rather than elasticized, such that they can either (preferably) expand over the combat boots, or be turned back safely over the calves to reach the PCPU waist when the lower garments are everted for removal. The addition of fastenings of hook-and-pile or other type is recommended, for a) securing the two garments together when worn (regardless of whether the CP socks or PCPU feet are added), b)

blousing the expandable ankle cuffs, and c) securing the bundled PCPU/BDUs (in Step 10) with the turned-back ankle cuffs.

4. In further research, the contamination that is herein referred to as "nonattributable" need not remain so. It is only nonattributable within the present dataset. If a redesigned PCPU were used in a similar study employing the revised Hasty Decon procedure, the predicted reduction in contamination would cause some of the variance to drop out of the analysis. It is likely that this reduction would allow some of the remaining variance to be captured by those procedural steps which, at present, produce contamination but do not get singled out by the analyses.

References

Birmingham, D. J. (1991). Occupational Dermatoses. In G. D. Clayton & F. E. Clayton (Eds.), Patty's Industrial Hygiene and Toxicology, 4th Ed., Vol. I, Part A. New York: Wiley.

Blewett, W. K., Jones, D. W., & Arca, V. J. (1991). Donning and doffing evaluation of the chemical protective undergarment. Aberdeen Proving Ground, MD: Physical Protection Directorate, Chemical Research, Development, and Engineering Center.

Department of the Army, (1985a). NBC Decontamination (Field Manual FM 3-5). Washington, DC: Department of the Army, Headquarters.

Department of the Army, (1985b). NBC Protection (Field Manual FM 3-4). Washington, DC: Department of the Army, Headquarters.

Fenske, R. A., Leffingwell, J. T., & Spear, R. C. (1985). Evaluation of fluorescent tracer methodology for dermal exposure assessment. In R. C. Honeycutt, G. Zewig, & N. N. Ragsdale (Eds.), Dermal Exposure Related to Pesticide Use: Discussion of Risk Assessment. Washington, DC: American Chemical Society.

Gordon, C. C., Bradtmiller, B., Churchill, T., Clauser, C. E., McConville, J. T., Tebbetts, I., and Walker, R. A. (1989). 1988 Anthropometric Survey of U.S. Army Personnel: Methods and Summary Statistics (Technical Report NATICK/TR-89/044). Natick, Massachusetts: U.S. Army Natick Research, Development, and Engineering Center.

Harrah, D. M., Bruno, R. S., & Weaver, B. C. (1990). Human Factors Evaluation of the Mission-Oriented Protective Posture (MOPP) Exchange Procedures (U). US Army Dugway Proving Ground, Dugway, UT: Technical Analysis and Information Center.

Harkins, H. N. (1942). The Treatment of Burns. Springfield, IL: Charles C Thomas.

Just, J. W. (N.d.) War Gases, Incendiaries, Infernal Machines, and Sabotage. University of Maryland College of Engineering.

National Aeronautic and Space Administration. (1989). Man-System Integration Standards NASA-STD-3000, Volume 1. Houston, TX: Lyndon B. Johnson Space Center, 1989.

Orton, R. (1990). National Chemical Warfare Policy and the Army Chemical Corps. In Proceedings of the Chemical/Biological Symposium on "Meeting the Chemical/Biological Defense Needs in the 90's" (Naval Surface Warfare Center - White Oak, Silver Spring, MD, (pp. 27-30). Washington, DC: American Defense

Preparedness Association.

Tregear, R. T. (1966). Physiological Functions of Skin. London: Academic Press.

Appendix A

Proposed PCPU Hasty Decon Procedure

Appendix A. Proposed CPU Hasty Decon Procedure

Following is the original version of the CPU hasty decon as used in the experiment.

Items to be REPLACED:
- Chemical Protective Undergarment (2 pc)
- overboots
- butyl gloves
- glove liners
- BDU trousers
- BDU coat

Items to be REUSED:
- NBC mask
- combat boots
- socks
- conventional undergarments

1. REMOVE BUDDY'S BDU COAT

Help buddy remove BDU coat. Buddy clenches fists to retain gloves as arms are withdrawn from sleeves.

Discard the coat.

2. DECON OWN GLOVES

Decontaminate your own gloves.

3. DECON BUDDY'S MASK

Decontaminate your buddy's mask. (If necessary, you may unfasten his or her hood.)

4. REMOVE BUDDY'S CPU TOP

4a) Buddy undoes waist-tabs and fly of BDU trousers, and turns down waist and seat portion inside-out to crotch level. Assist if needed.

4b) Unfasten buddy's hood. Pull edge of hood forward and fold it back about 1 inch. Unzip buddy's CPU top. Grasp back of buddy's hood, and carefully pull it off head.

4c) Have buddy clench fists to retain gloves. Remove buddy's CPU top, letting the garment turn completely inside-out. Both of you must not touch the inner lining.

4d) Spread CPU top on ground with inside surface facing up, and arms spread out. The lining of this garment will be a "safe zone" for your buddy to sit on later; be careful not to contaminate it.

5. REMOVE BUDDY'S OVERBOOTS

5a) Roll up buddy's BDU trouser legs to just below knees.

5b) Decontaminate the upper shaft of buddy's overboots around the opening.

5c) Have your buddy stand next to the safe zone. Carefully remove buddy's overboots; buddy steps onto safe zone as each foot is withdrawn.

6. ROLL BUDDY'S TROUSERS

Roll down the hip and thigh portion of buddy's trousers to just above the knee level.

7. BUDDY REMOVES CP GLOVES

Your buddy removes his or her CP gloves; liners can be retained for slight protection until replaced. Assist as needed with glove removal.

Discard the gloves.

8. BUDDY TURNS DOWN LOWER CPU

Buddy slips hands inside CPU waistband, spreads waistband, and turns garment down over knees to cover bunched-up BDU trousers. The CPU and the BDUs should form a bundle about the knees, with only the inside lining of the CPU exposed.

Your buddy is now in a very vulnerable state. At this point you are the biggest threat to your buddy, so exercise caution from this point on.

9. BUDDY REMOVES COMBAT BOOTS

9a) Have your buddy sit on the safe zone, unassisted.

9b) Buddy carefully removes combat boots, and stands each boot on an arm of spread CP garment.

9c) Remind your buddy to readjust bootlaces for redonning (because boots will be put on while gloved).

10. HELP REMOVE LOWER CPU AND BDU PANTS

Buddy inserts right hand down inner side of the left leg of the CPU, and grasps top of sock. Left hand goes inside CPU down outer side of left leg and spreads CPU cuff opening. While holding onto sock, buddy removes left leg from bundled pants/CPU. Garment bundle must not come undone. You may help buddy if needed, being careful not to touch his or her feet.

Buddy repeats with opposite leg.

If you do not touch the outside of the bundle (i.e. the uncontaminated lining of the lower CPU), then it may be set aside for use as additional safe-surface support. If you have touched the outside of the bundle, discard it.

11. NEW CPU AND GLOVES

Have your buddy stand up.

Open a new CPU package without touching the garments inside. Buddy extracts the new CPU without touching the outside of the package, and sets aside the CPU top on the safe zone.

11a) CP bottom: Buddy dons new CPU bottom; while he or she does this, you open new CP glove/boot package without touching contents.

11b) CP top: Buddy dons new CPU top and fastens hood; leaves top untucked outside of CPU waistband.

11c) CP gloves: Buddy discards old glove liners if they are still on. Buddy extracts new CP liners and gloves without touching outer package, and dons them.

12. NEW BDU, OLD COMBAT BOOTS

Open new BDU package without touching contents. Buddy extracts new BDU without touching outer package.

12a) Buddy dons new BDU trousers, tucks CPU top into BDU waist (not into CPU waist), and dons new BDU coat.

12b) Instruct your buddy to adjust the lacing of his or her combat boots and then redon them.

12c) Buddy extracts new CP overboots without touching outer package, and dons them.

13. SWITCH ROLES

If this is the first pass through the procedure, switch roles with your buddy and repeat from step 1, otherwise proceed to step 14.

14. GLOVE DECON

The soldier who was the <u>first</u> to be deconned now decontaminates his or her own gloves.

* * * DONE * * *

Appendix B

PCPU Hasty Decon Perceived Hazard Questionnaire

Appendix B. PCPU Hasty Decon Perceived Hazard Questionnaire

Pair#: ____ Subject#: ____ Date: _______

INSTRUCTIONS:

For each step in the decontamination procedure, indicate how safe or hazardous you think the step is for the soldier who is being decontaminated (the "buddy" role). Select your answer based on your experience in both roles.

	SAFE						HAZARDOUS
1. REMOVE BUDDY'S BDU COAT	1	2	3	4	5	6	7
2. (n.a.)							
3. DECON BUDDY'S MASK	1	2	3	4	5	6	7
4. REMOVE BUDDY'S PCPU TOP							
4a) Buddy turns down trousers	1	2	3	4	5	6	7
4b) Pull off buddy's hood	1	2	3	4	5	6	7
4c) Remove buddy's CP top	1	2	3	4	5	6	7
4d) Spread CP top on ground	1	2	3	4	5	6	7
5. REMOVE BUDDY'S OVERBOOTS							
5a) Roll buddy's pant legs	1	2	3	4	5	6	7
5b) Decon buddy's overboots	1	2	3	4	5	6	7
5c) Remove buddy's overboots	1	2	3	4	5	6	7
6. ROLL BUDDY'S PANTS FOR REMOVAL	1	2	3	4	5	6	7
7. BUDDY REMOVES CP GLOVES	1	2	3	4	5	6	7
8. BUDDY TURNS DOWN LOWER CPU	1	2	3	4	5	6	7
9. BUDDY REMOVES COMBAT BOOTS							
9a) Buddy sits on safe zone	1	2	3	4	5	6	7
9b) Buddy removes boots	1	2	3	4	5	6	7
9c) Buddy adjusts bootlaces	1	2	3	4	5	6	7
10. HELP REMOVE LOWER CPU & PANTS	1	2	3	4	5	6	7
11a. BUDDY DONS CPU BOTTOM	1	2	3	4	5	6	7
11b. BUDDY DONS CPU TOP	1	2	3	4	5	6	7
11c. BUDDY DONS GLOVES	1	2	3	4	5	6	7
12a. BUDDY DONS BDUs	1	2	3	4	5	6	7
12b. BUDDY DONS COMBAT BOOTS	1	2	3	4	5	6	7
12c. BUDDY DONS NEW OVERBOOTS	1	2	3	4	5	6	7
13. (n.a.)							
14. (n.a.)							

Appendix C

Contamination Data Tables for Individual Subjects

Appendix C. Contamination Data Tables for Individual Subjects

Table C-1. Nondermal Events per Subject (N = 12), by Procedural Step

		Pair												
		I		II		III		IV		V		VI		
		Subject												
Procedural Step		1	2	3	4	5	6	7	8	9	10	11	12	ALL
1	Remove BDU coat	.	.	.	.	.	.	.	.	.	.	.	.	0
2	Decon own gloves	.	.	.	.	.	.	.	.	.	.	.	.	0
3	Decon mask	.	.	.	.	.	.	.	.	.	.	.	.	0
4a	B. everts pants	.	.	.	.	.	.	.	.	.	.	.	.	0
4b	Pull off hood	.	.	.	.	.	.	.	.	.	.	.	.	0
4c	Remove CP top	.	.	.	.	.	.	.	.	.	.	.	.	0
4d	Spread CP top	.	.	.	.	.	.	.	.	.	.	.	.	0
5a	Roll pant legs	.	.	.	.	1	.	.	.	.	.	.	.	1
5b	Decon overboots	.	.	.	1	.	.	.	.	1	.	.	.	2
5c	Remove overboots	1	.	.	.	.	.	.	.	.	.	.	.	1
6	Roll BDU pants	.	.	.	.	.	.	.	.	.	.	.	.	0
7	B. doffs gloves	.	.	.	.	.	.	.	.	.	.	.	.	0
8	B. lowers CPU	.	.	.	.	1	.	.	.	.	.	.	.	1
9a	B. sits	.	.	.	.	.	.	.	.	.	.	.	.	0
9b	B. doffs boots	.	1	.	.	.	.	.	.	.	.	.	.	1
9c	B. adjusts laces	.	.	.	.	.	.	.	.	.	.	.	.	0
10	B. doffs lower CPU	.	.	.	.	.	.	.	.	.	.	.	.	0
11a	B. dons lower CPU	.	.	.	1	.	.	.	.	.	.	.	.	1
11b	B. dons top CPU	.	.	.	.	.	.	.	.	.	.	.	.	0
11c	B. dons gloves	.	.	1	.	.	.	.	.	.	.	.	.	1
12a	B. dons BDUs	.	.	.	.	.	.	.	.	.	.	.	.	0
12b	B. dons boots	.	.	.	1	.	.	.	.	1	.	.	.	2
12c	B. dons overboots	.	2	.	.	.	2	.	.	.	.	.	1	5
Decon Total		1	3	1	3	2	2	0	0	2	0	0	1	15

Table C-2. Dermal Events per Subject ($\underline{N}$ = 12), by Procedural Step

	Pair												
	I		II		III		IV		V		VI		
	Subject												
Procedural Step	1	2	3	4	5	6	7	8	9	10	11	12	ALL
1 Remove BDU coat	.	.	.	.	.	.	.	.	.	.	.	.	0
2 Decon own gloves	.	.	.	.	.	.	.	.	.	.	.	.	0
3 Decon mask	.	.	.	.	.	.	.	.	.	.	.	.	0
4a B. everts pants	.	.	.	1	.	.	.	.	.	.	.	.	1
4b Pull off hood	1	.	.	1	.	.	.	.	.	.	.	.	2
4c Remove CP top	.	.	.	.	.	.	.	.	.	.	.	.	0
4d Spread CP top	1	.	.	.	.	.	.	.	.	.	.	.	1
5a Roll pant legs	.	1	.	1	.	1	.	.	.	.	1	2	6
5b Decon overboots	.	.	.	.	.	1	.	1	.	1	.	.	3
5c Remove overboots	2	.	.	1	.	.	.	.	.	.	.	.	3
6 Roll BDU pants	.	.	.	.	.	.	.	1	.	.	.	.	1
7 B. doffs gloves	.	.	1	.	.	.	.	.	.	.	1	1	3
8 B. lowers CPU	1	.	.	.	1	.	.	.	2	.	.	.	4
9a B. sits	.	.	.	.	.	.	1	.	2	.	.	.	3
9b B. doffs boots	2	.	1	.	.	.	2	1	.	.	.	.	6
9c B. adjusts laces	.	1	.	.	.	.	.	.	.	.	.	1	2
10 B. doffs lower CPU	2	1	2	.	1	.	2	.	.	.	1	.	9
11a B. dons lower CPU	1	1	.	1	1	.	.	.	.	.	.	.	4
11b B. dons top CPU	.	.	.	.	.	.	.	1	.	.	1	.	2
11c B. dons gloves	.	.	.	.	.	.	.	.	.	.	1	.	1
12a B. dons BDUs	.	1	.	.	.	.	1	.	1	1	.	.	4
12b B. dons boots	.	.	.	.	.	.	.	.	.	.	1	.	1
12c B. dons overboots	.	.	.	.	2	.	.	.	.	.	.	.	2
Decon Total	10	5	4	5	5	2	6	4	5	2	6	4	58

Table C-3. Nondermal Loci per Subject ($\underline{N}$ = 12), by Procedural Step

	Pair												
	I		II		III		IV		V		VI		
	Subject												
Procedural Step	1	2	3	4	5	6	7	8	9	10	11	12	ALL
1 Remove BDU coat	.	.	.	.	.	.	.	.	.	.	.	.	0
2 Decon own gloves	.	.	.	.	.	.	.	.	.	.	.	.	0
3 Decon mask	.	.	.	.	.	.	.	.	.	.	.	.	0
4a B. everts pants	.	.	.	.	.	.	.	.	.	.	.	.	0
4b Pull off hood	.	.	.	.	.	.	.	.	.	.	.	.	0
4c Remove CP top	.	.	.	.	.	.	.	.	.	.	.	.	0
4d Spread CP top	.	.	.	.	.	.	.	.	.	.	.	.	0
5a Roll pant legs	.	.	.	.	2	.	.	.	.	.	.	.	2
5b Decon overboots	.	.	.	1	.	.	.	.	1	.	.	.	2
5c Remove overboots	1	.	.	.	.	.	.	.	.	.	.	.	1
6 Roll BDU pants	.	.	.	.	.	.	.	.	.	.	.	.	0
7 B. doffs gloves	.	.	.	.	.	.	.	.	.	.	.	.	0
8 B. lowers CPU	.	.	.	.	1	.	.	.	.	.	.	.	1
9a B. sits	.	.	.	.	.	.	.	.	.	.	.	.	0
9b B. doffs boots	.	2	.	.	.	.	.	.	.	.	.	.	2
9c B. adjusts laces	.	.	.	.	.	.	.	.	.	.	.	.	0
10 B. doffs lower CPU	.	.	.	.	.	.	.	.	.	.	.	.	0
11a B. dons lower CPU	.	.	.	1	.	.	.	.	.	.	.	.	1
11b B. dons top CPU	.	.	.	.	.	.	.	.	.	.	.	.	0
11c B. dons gloves	.	.	2	.	.	.	.	.	.	.	.	.	2
12a B. dons BDUs	.	.	.	.	.	.	.	.	.	.	.	.	0
12b B. dons boots	.	.	.	1	.	.	.	.	2	.	.	.	3
12c B. dons overboots	.	2	.	.	.	4	.	.	.	.	.	1	7
Decon Total	1	4	2	3	3	4	0	0	3	0	0	1	21

Table C-4. Dermal Loci per Subject (N = 12), by Procedural Step

	Pair												
	I		II		III		IV		V		VI		
	Subject												
Procedural Step	1	2	3	4	5	6	7	8	9	10	11	12	ALL
1 Remove BDU coat	.	.	.	.	.	.	.	.	.	.	.	.	0
2 Decon own gloves	.	.	.	.	.	.	.	.	.	.	.	.	0
3 Decon mask	.	.	.	.	.	.	.	.	.	.	.	.	0
4a B. everts pants	.	.	.	1	.	.	.	.	.	.	.	.	1
4b Pull off hood	1	.	.	1	.	.	.	.	.	.	.	.	2
4c Remove CP top	.	.	.	.	.	.	.	.	.	.	.	.	0
4d Spread CP top	1	.	.	.	.	.	.	.	.	.	.	.	1
5a Roll pant legs	.	1	.	1	.	1	.	.	.	.	1	2	6
5b Decon overboots	.	.	.	.	.	2	.	1	.	1	.	.	4
5c Remove overboots	4	.	.	4	.	.	.	.	.	.	.	.	8
6 Roll BDU pants	.	.	.	.	.	.	.	1	.	.	.	.	1
7 B. doffs gloves	.	.	1	.	.	.	.	.	.	.	2	2	5
8 B. lowers CPU	2	.	.	.	1	.	.	.	2	.	.	.	5
9a B. sits	.	.	.	.	.	.	1	.	4	.	.	.	5
9b B. doffs boots	2	.	1	.	.	.	2	4	.	.	.	.	9
9c B. adjusts laces	.	2	.	.	.	.	.	.	.	.	.	1	3
10 B. doffs lower CPU	2	4	3	.	2	.	2	.	.	.	6	.	19
11a B. dons lower CPU	1	1	.	1	2	.	.	.	.	.	.	.	5
11b B. dons top CPU	.	.	.	.	.	.	.	1	.	.	3	.	4
11c B. dons gloves	.	.	.	.	.	.	.	.	.	.	1	.	1
12a B. dons BDUs	.	4	.	.	.	.	1	.	1	2	.	.	8
12b B. dons boots	.	.	.	.	.	.	.	.	.	.	1	.	1
12c B. dons overboots	.	.	.	.	2	.	.	.	.	.	.	.	2
Decon Total	13	12	5	8	7	3	6	7	7	3	14	5	90

Table C-5. Total Events per Subject ($\underline{N}$ = 12), by Procedural Step

Procedural Step		Pair I		Pair II		Pair III		Pair IV		Pair V		Pair VI		
		Subject 1	2	3	4	5	6	7	8	9	10	11	12	ALL
1	Remove BDU coat	.	.	.	.	.	.	.	.	.	.	.	.	0
2	Decon own gloves	.	.	.	.	.	.	.	.	.	.	.	.	0
3	Decon mask	.	.	.	.	.	.	.	.	.	.	.	.	0
4a	B. everts pants	.	.	.	1	.	.	.	.	.	.	.	.	1
4b	Pull off hood	1	.	.	1	.	.	.	.	.	.	.	.	2
4c	Remove CP top	.	.	.	.	.	.	.	.	.	.	.	.	0
4d	Spread CP top	1	.	.	.	.	.	.	.	.	.	.	.	1
5a	Roll pant legs	.	1	.	1	1	1	.	.	.	.	1	2	7
5b	Decon overboots	.	.	.	1	.	1	1	1	.	1	.	.	5
5c	Remove overboots	3	.	.	1	.	.	.	.	.	.	.	.	4
6	Roll BDU pants	.	.	.	.	.	.	.	1	.	.	.	.	1
7	B. doffs gloves	.	.	1	.	.	.	.	.	.	.	1	1	3
8	B. lowers CPU	1	.	.	.	2	.	.	.	2	.	.	.	5
9a	B. sits	.	.	.	.	.	.	1	.	2	.	.	.	3
9b	B. doffs boots	2	1	1	.	.	.	2	1	.	.	.	.	7
9c	B. adjusts laces	.	1	.	.	.	.	.	.	.	.	.	1	2
10	B. doffs lower CPU	2	1	2	.	1	.	2	.	.	.	1	.	9
11a	B. dons lower CPU	1	1	.	2	1	.	.	.	.	.	.	.	5
11b	B. dons top CPU	.	.	.	.	.	.	.	1	.	.	1	.	2
11c	B. dons gloves	.	.	1	.	.	.	.	.	.	.	1	.	2
12a	B. dons BDUs	.	1	.	.	.	.	1	.	1	1	.	.	4
12b	B. dons boots	.	.	.	1	.	.	.	.	1	.	1	.	3
12c	B. dons overboots	.	2	.	.	2	2	.	.	.	.	.	1	7
Decon Total		11	8	5	8	7	4	6	4	7	2	6	5	73

Table C-6. Total Loci per Subject ($\underline{N}$ = 12), by Procedural Step

	Pair												
	I		II		III		IV		V		VI		
	Subject												
Procedural Step	1	2	3	4	5	6	7	8	9	10	11	12	ALL
1 Remove BDU coat	.	.	.	.	.	.	.	.	.	.	.	.	0
2 Decon own gloves	.	.	.	.	.	.	.	.	.	.	.	.	0
3 Decon mask	.	.	.	.	.	.	.	.	.	.	.	.	0
4a B. everts pants	.	.	.	1	.	.	.	.	.	.	.	.	1
4b Pull off hood	1	.	.	1	.	.	.	.	.	.	.	.	2
4c Remove CP top	.	.	.	.	.	.	.	.	.	.	.	.	0
4d Spread CP top	1	.	.	.	.	.	.	.	.	.	.	.	1
5a Roll pant legs	.	1	.	1	2	1	.	.	.	.	1	2	8
5b Decon overboots	.	.	.	1	.	2	1	1	.	1	.	.	6
5c Remove overboots	5	.	.	4	.	.	.	.	.	.	.	.	9
6 Roll BDU pants	.	.	.	.	.	.	.	1	.	.	.	.	1
7 B. doffs gloves	.	.	1	.	.	.	.	.	.	.	2	2	5
8 B. lowers CPU	2	.	.	.	2	.	.	.	2	.	.	.	6
9a B. sits	.	.	.	.	.	.	1	.	4	.	.	.	5
9b B. doffs boots	2	2	1	.	.	.	2	4	.	.	.	.	11
9c B. adjusts laces	.	2	.	.	.	.	.	.	.	.	.	1	3
10 B. doffs lower CPU	2	4	3	.	2	.	2	.	.	.	6	.	19
11a B. dons lower CPU	1	1	.	2	2	.	.	.	.	.	.	.	6
11b B. dons top CPU	.	.	.	.	.	.	.	1	.	.	3	.	4
11c B. dons gloves	.	.	2	.	.	.	.	.	.	.	1	.	3
12a B. dons BDUs	.	4	.	.	.	.	1	.	1	2	.	.	8
12b B. dons boots	.	.	.	1	.	.	.	.	2	.	1	.	4
12c B. dons overboots	.	2	.	.	2	4	.	.	.	.	.	1	9
Decon Total	14	16	7	11	10	7	7	7	9	3	14	6	112

Appendix D

Somatic Maps of Contamination
Within Procedural Step, Across Subjects

Appendix D. Somatic Maps of Contamination Within Procedural Step, Across Subjects

Eac} : the following figures represents all contaminative events (t . dermal and nondermal) that occurred within a single procedurai step of the PCPU hasty decon, across all subjects. The locus of contamination is indicated graphically; the number indicates the recipient subject.

Contaminations that are located at the coronal plane, or that are otherwise ambiguous as to dorsal/ventral classification, are depicted on the linear boundary of the figure. (Examples of such loci include the sole of the foot, the top of the head, and the inside of the ankle.)

The numerosity of these contaminations is equal to or greater than the Total Events for the subject/step, but may be less than the Total Loci data, since closely adjacent traces of simulant cannot be discretely indicated at this graphic scale.

Nondermal contaminations, which occurred only on the foot regions (i.e., the combat boots), can be distinguished from dermal foot contaminations by referring to the step number to determine if the combat boots were on at that point in the decon.

The maps begin with Step 4a because no contamination events occurred in Steps 1-3.

The silhouette is arbitrary and does not represent either the gender or anthropometry of the subjects.

STEP 4a

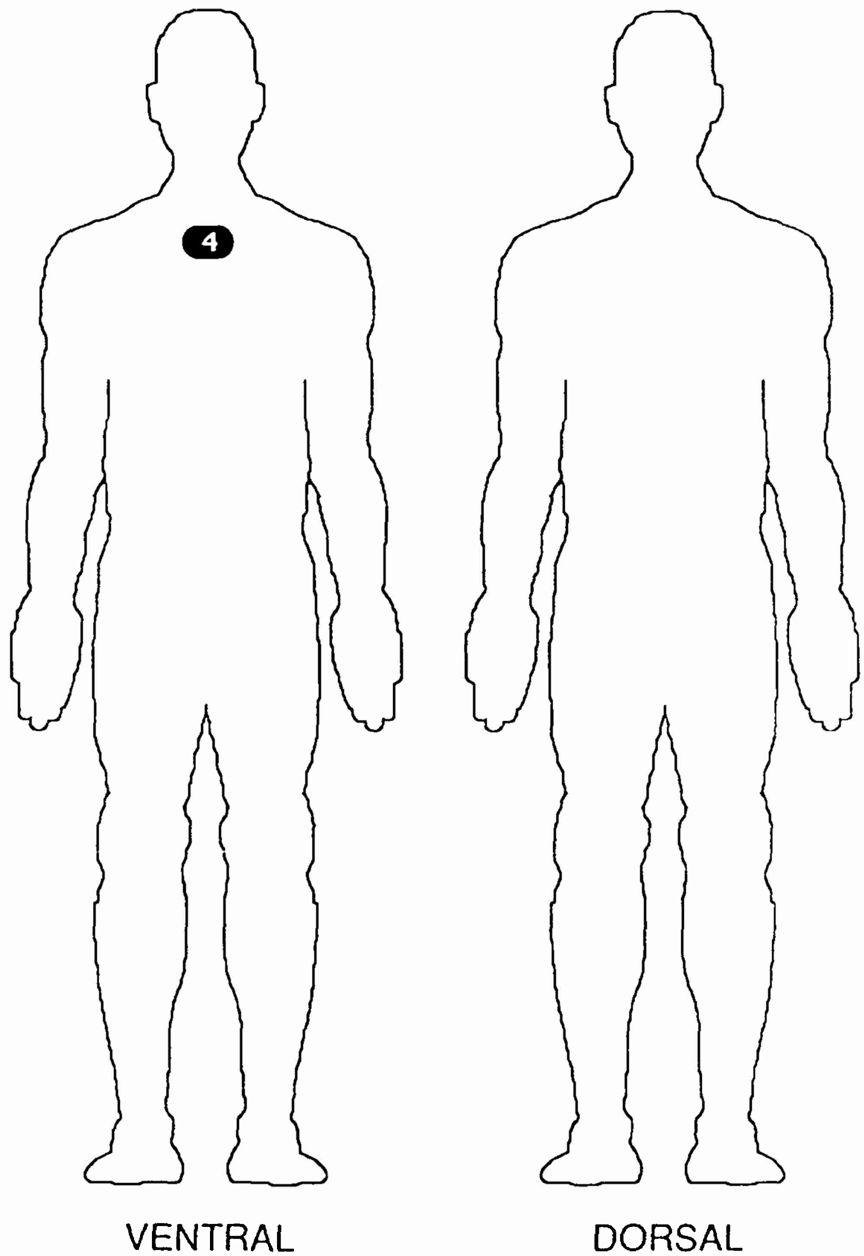


Figure D-1. Somatic map of contamination in Step 4a. The number at each locus identifies the experimental subject who became contaminated there during this step.

STEP 4b

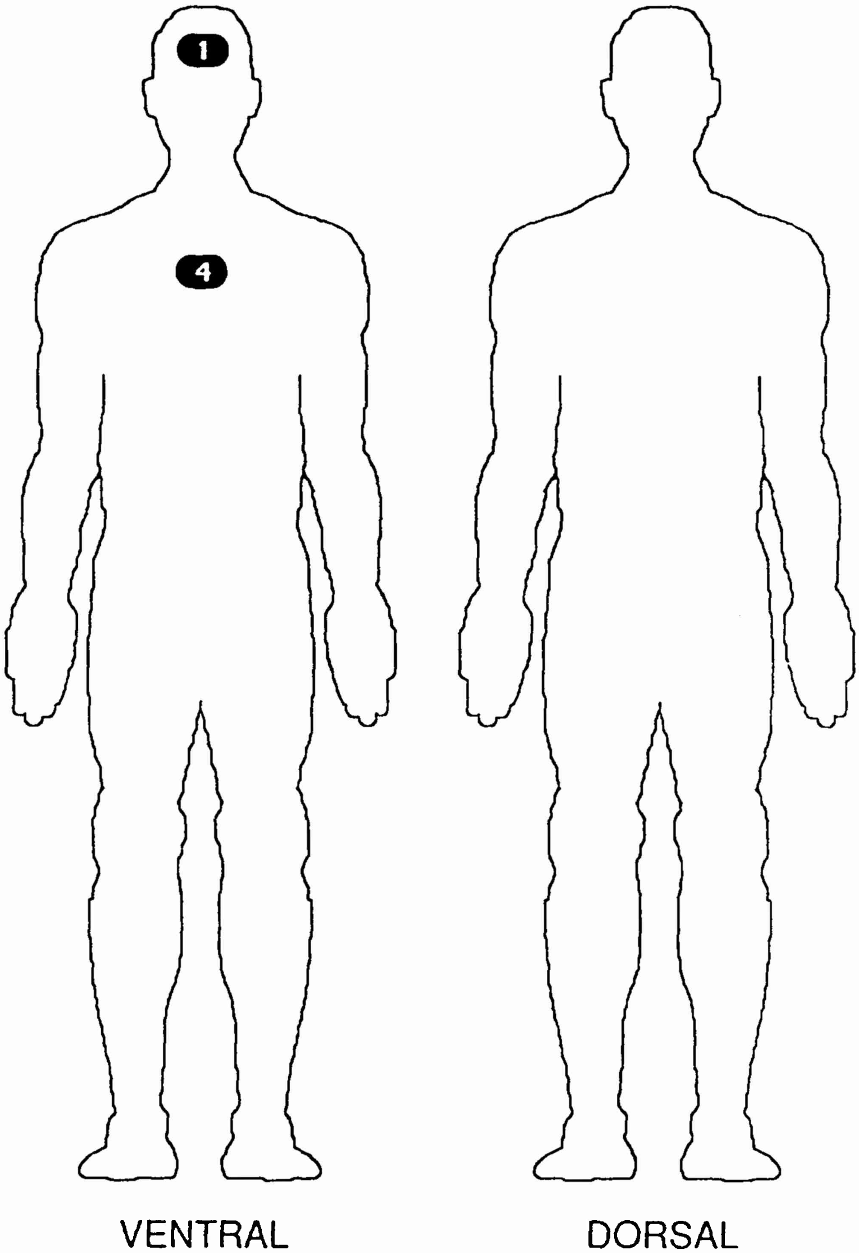


Figure D-2. Somatic map of contamination in Step 4b. The number at each locus identifies the experimental subject who became contaminated there during this step.

STEP 4c

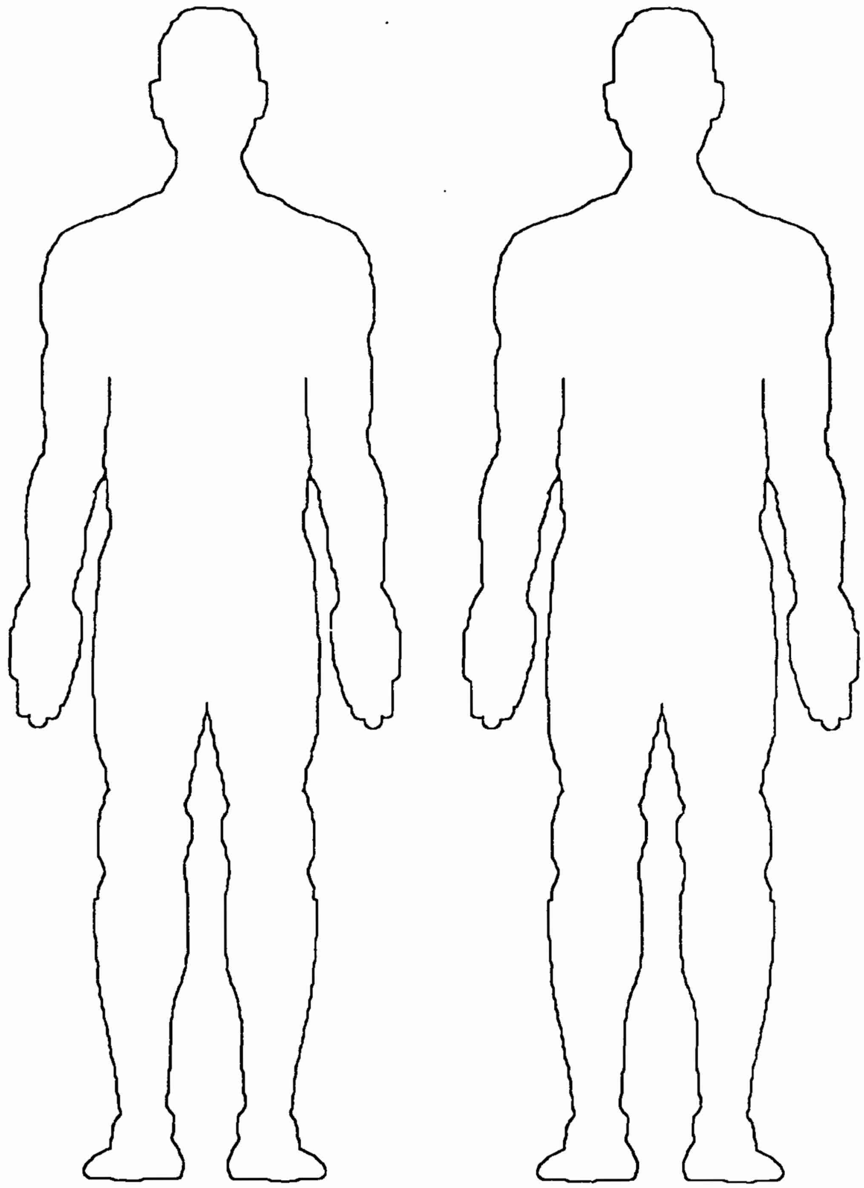


Figure D-3. Somatic map of contamination in Step 4c. (None of the subjects received contamination in this step.)

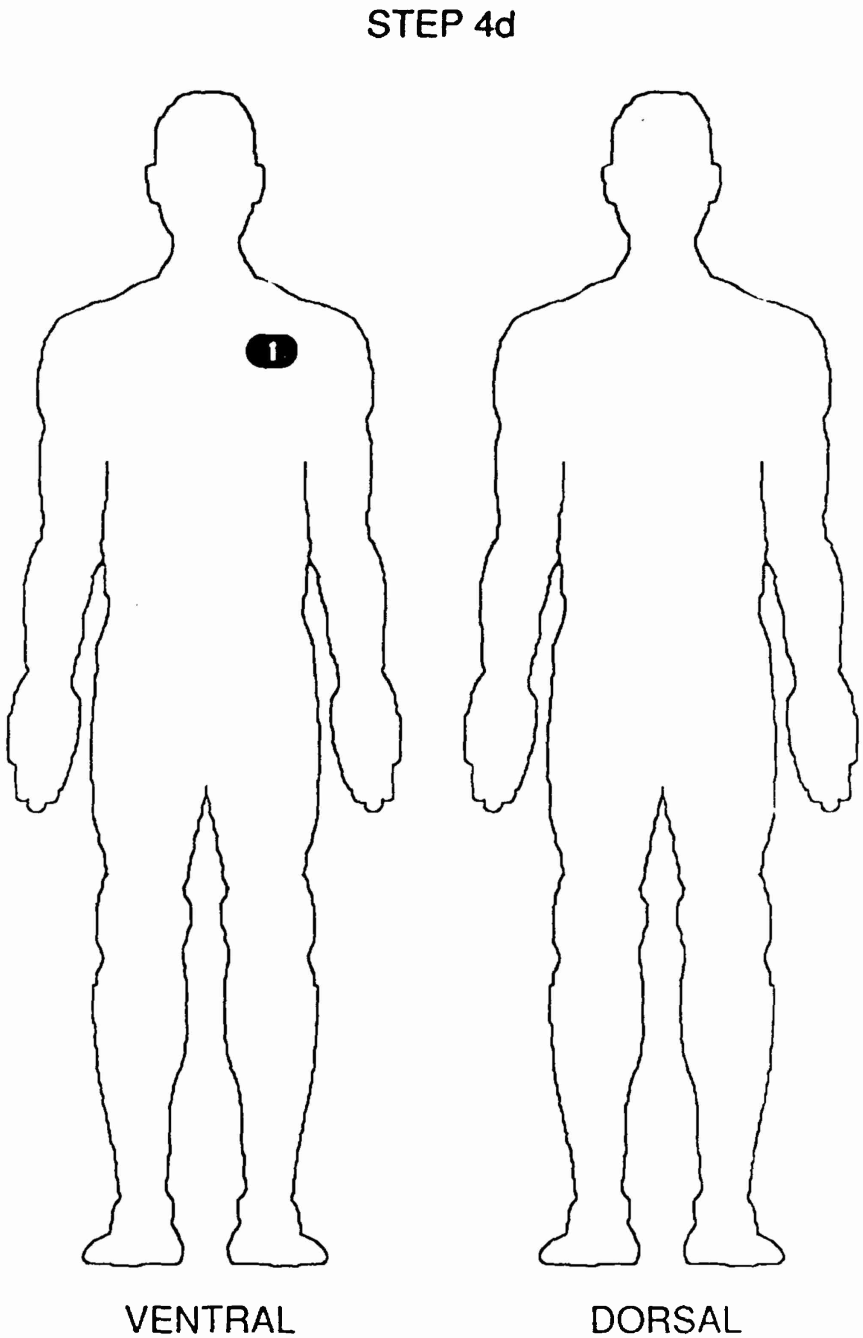


Figure D-4. Somatic map of contamination in Step 4d. The number at each locus identifies the experimental subject who became contaminated there during this step.

STEP 5a

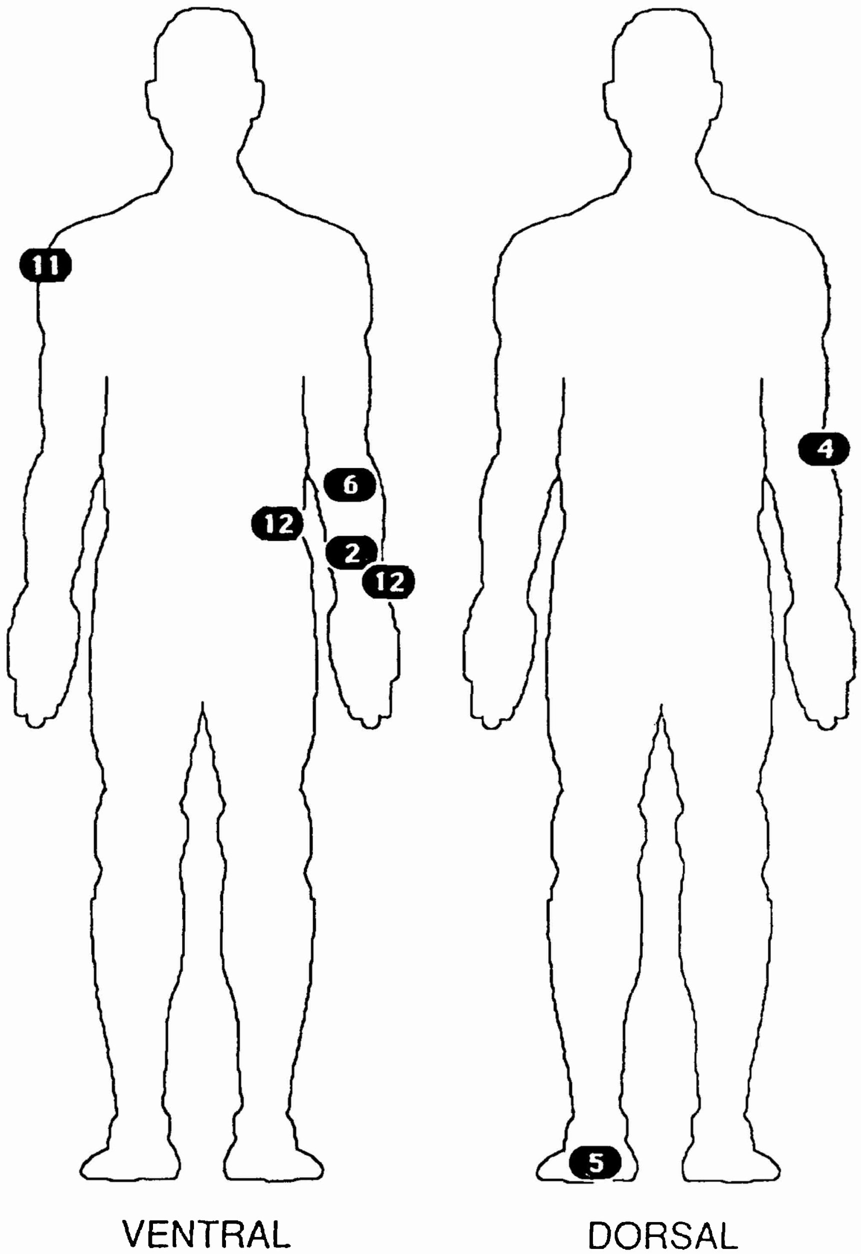


Figure D-5. Somatic map of contamination in Step 5a. The number at each locus identifies the experimental subject who became contaminated there during this step.

STEP 5b

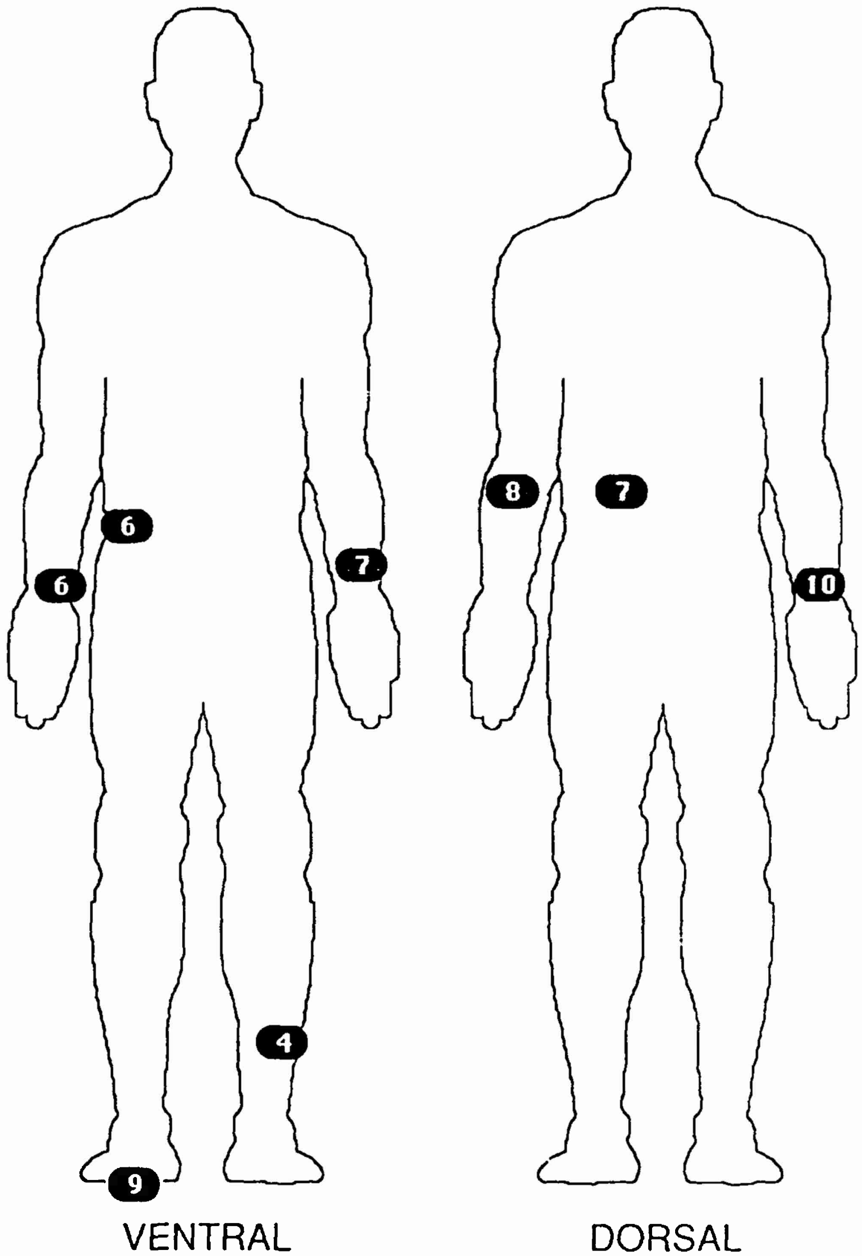


Figure D-6. Somatic map of contamination in Step 5b. The number at each locus identifies the experimental subject who became contaminated there during this step.

STEP 5c

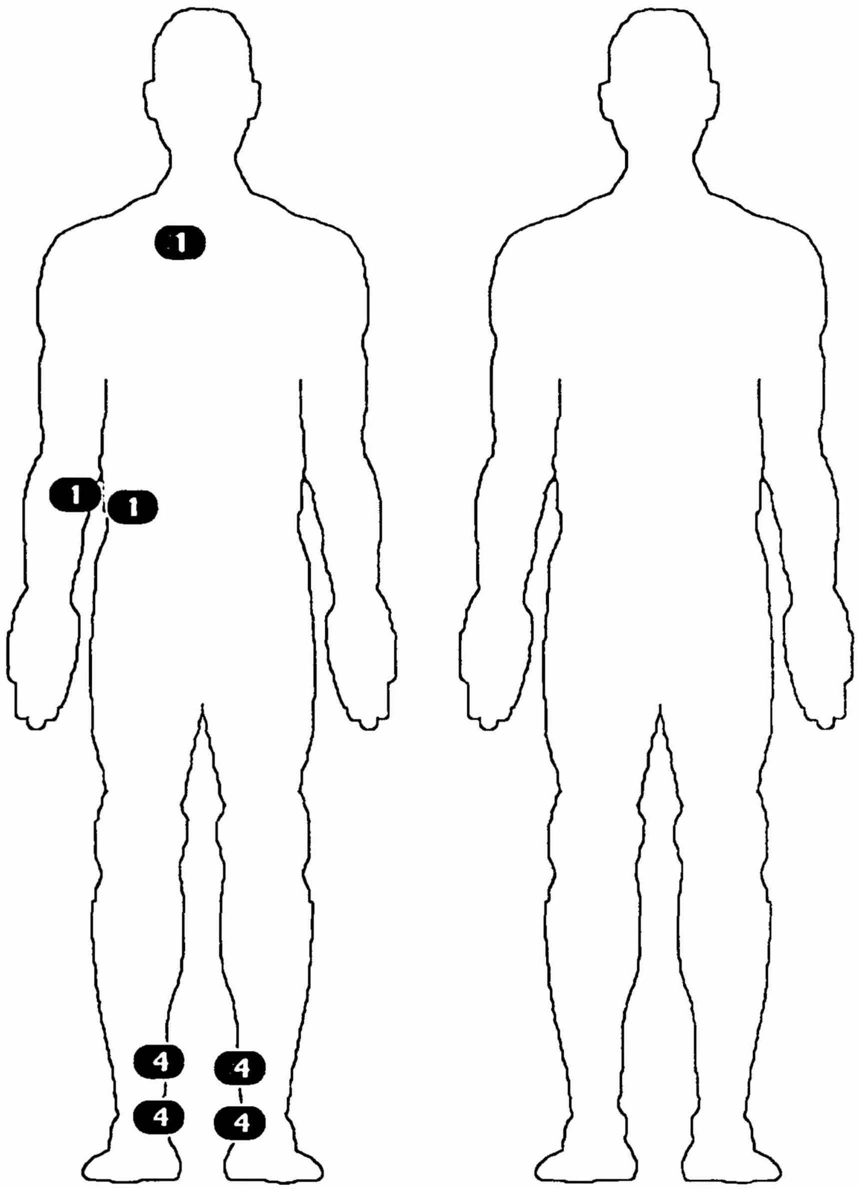


Figure D-7. Somatic map of contamination in Step 5c. The number at each locus identifies the experimental subject who became contaminated there during this step.

STEP 6

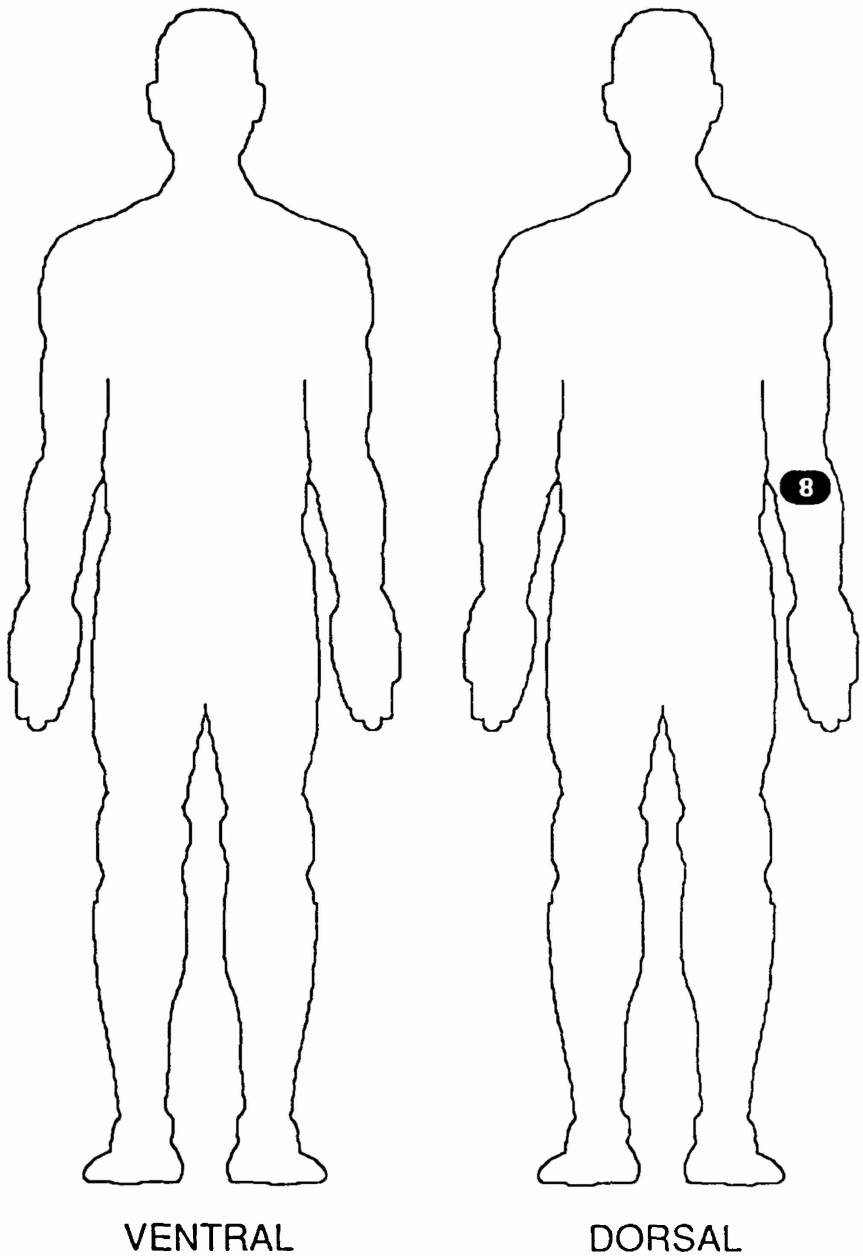


Figure D-8. Somatic map of contamination in Step 6. The number at each locus identifies the experimental subject who became contaminated there during this step.

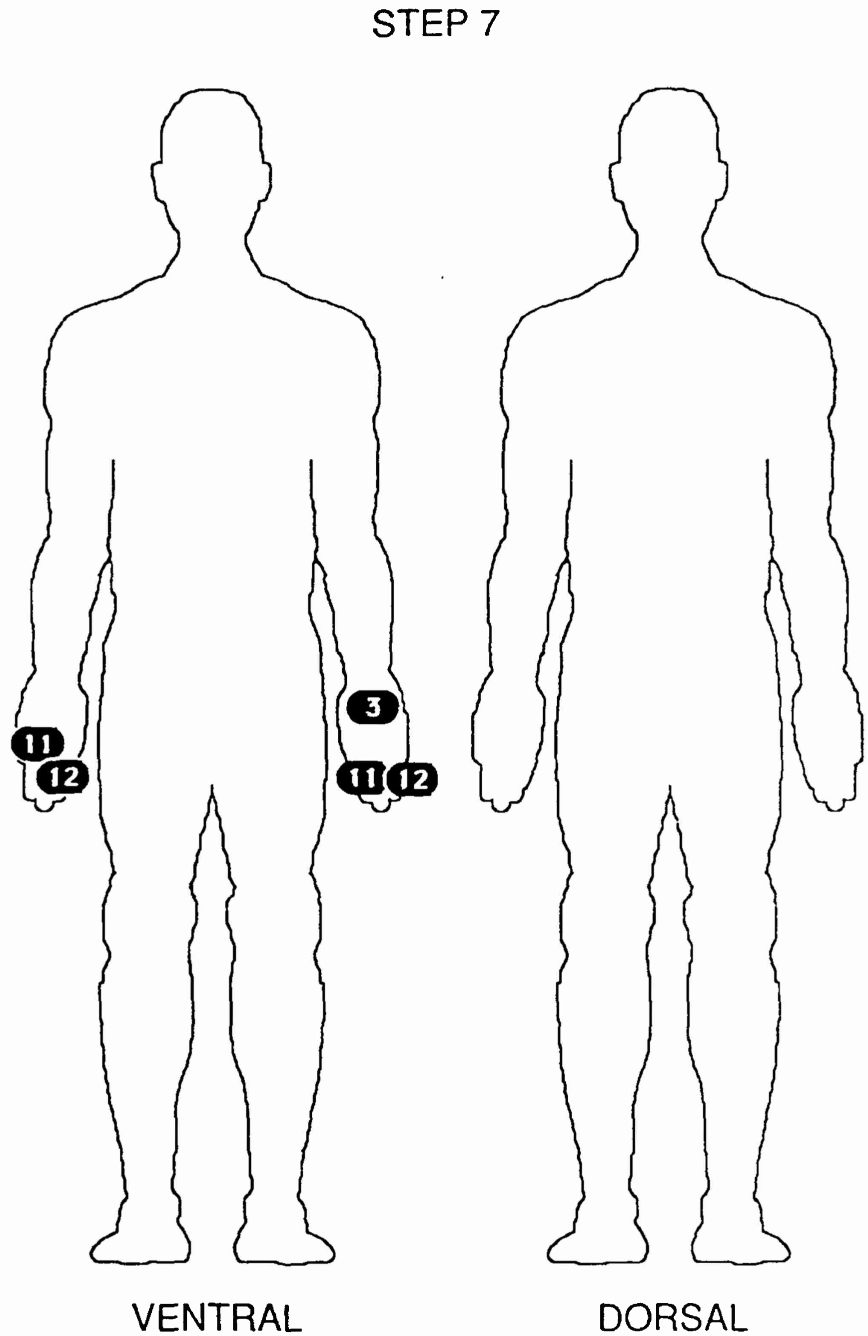


Figure D-9. Somatic map of contamination in Step 7. The number at each locus identifies the experimental subject who became contaminated there during this step.

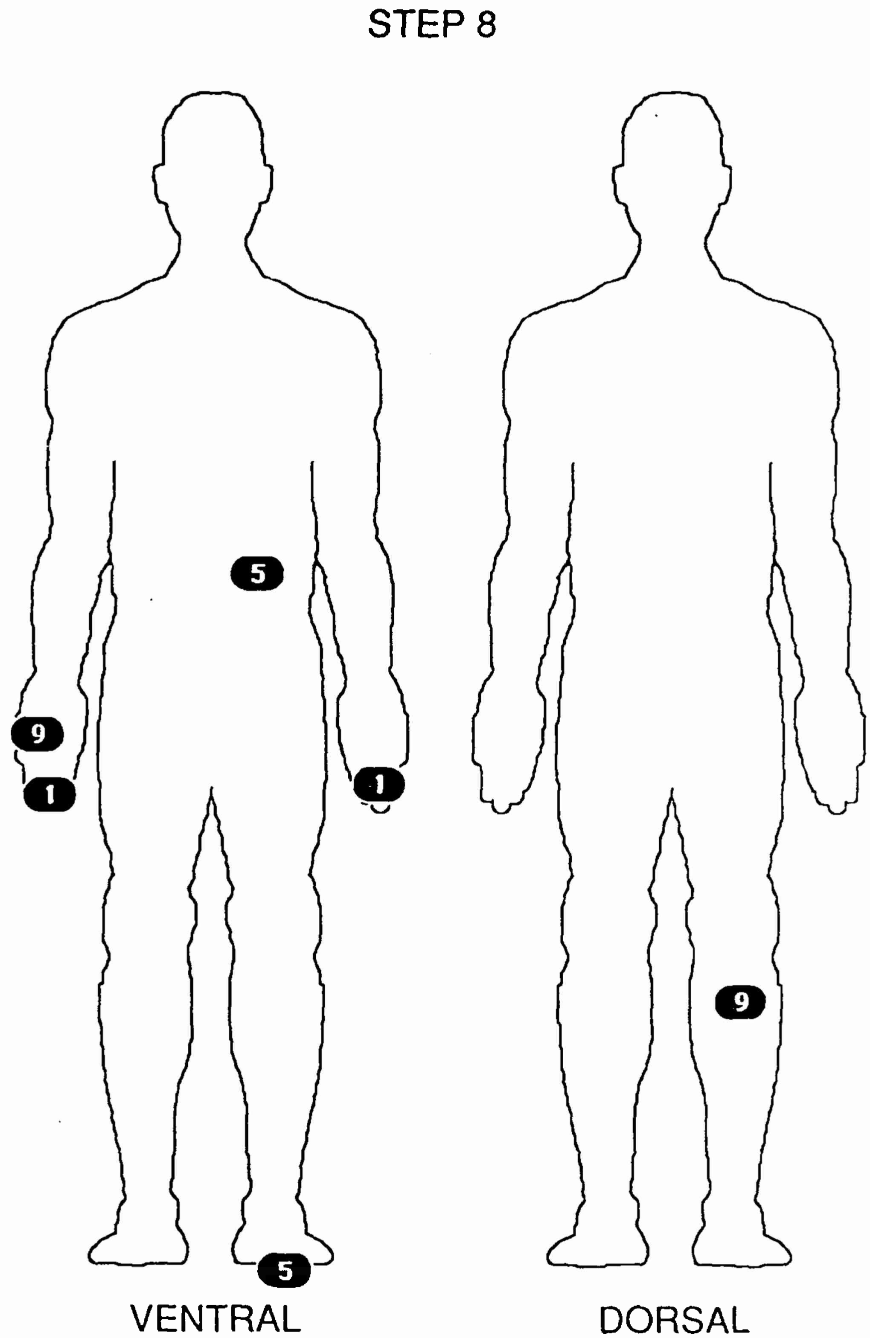


Figure D-10. Somatic map of contamination in Step 8. The number at each locus identifies the experimental subject who became contaminated there during this step.

STEP 9a

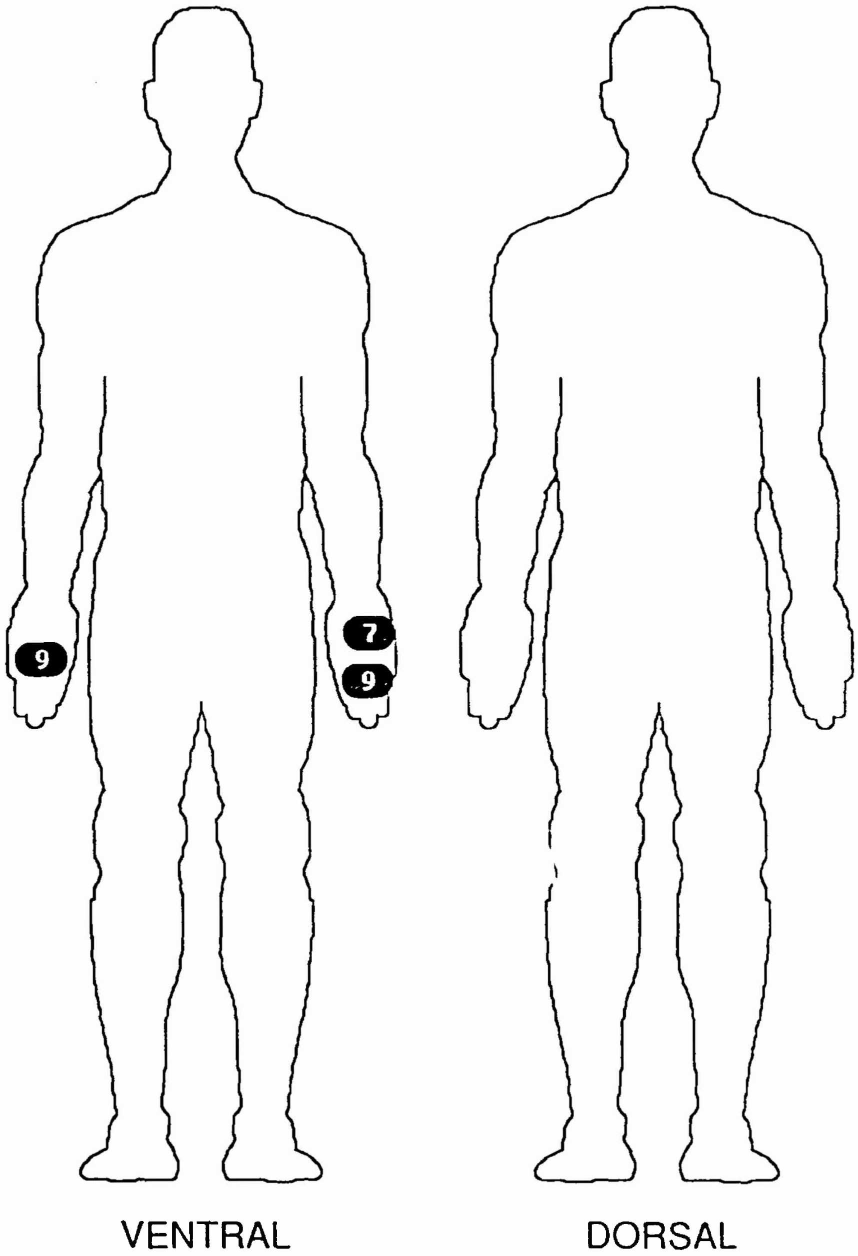


Figure D-11. Somatic map of contamination in Step 9a. The number at each locus identifies the experimental subject who became contaminated there during this step.

STEP 9b

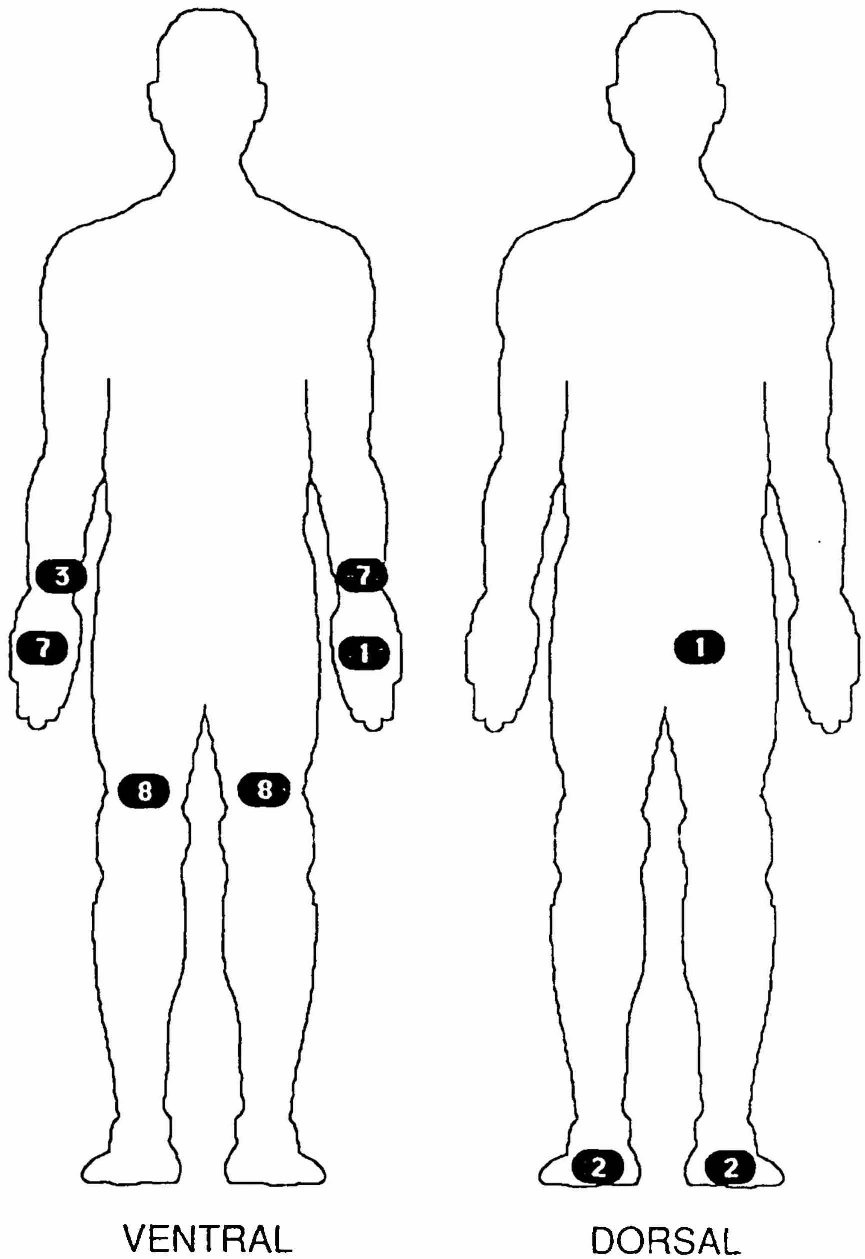


Figure D-12. Somatic map of contamination in Step 9b. The number at each locus identifies the experimental subject who became contaminated there during this step.

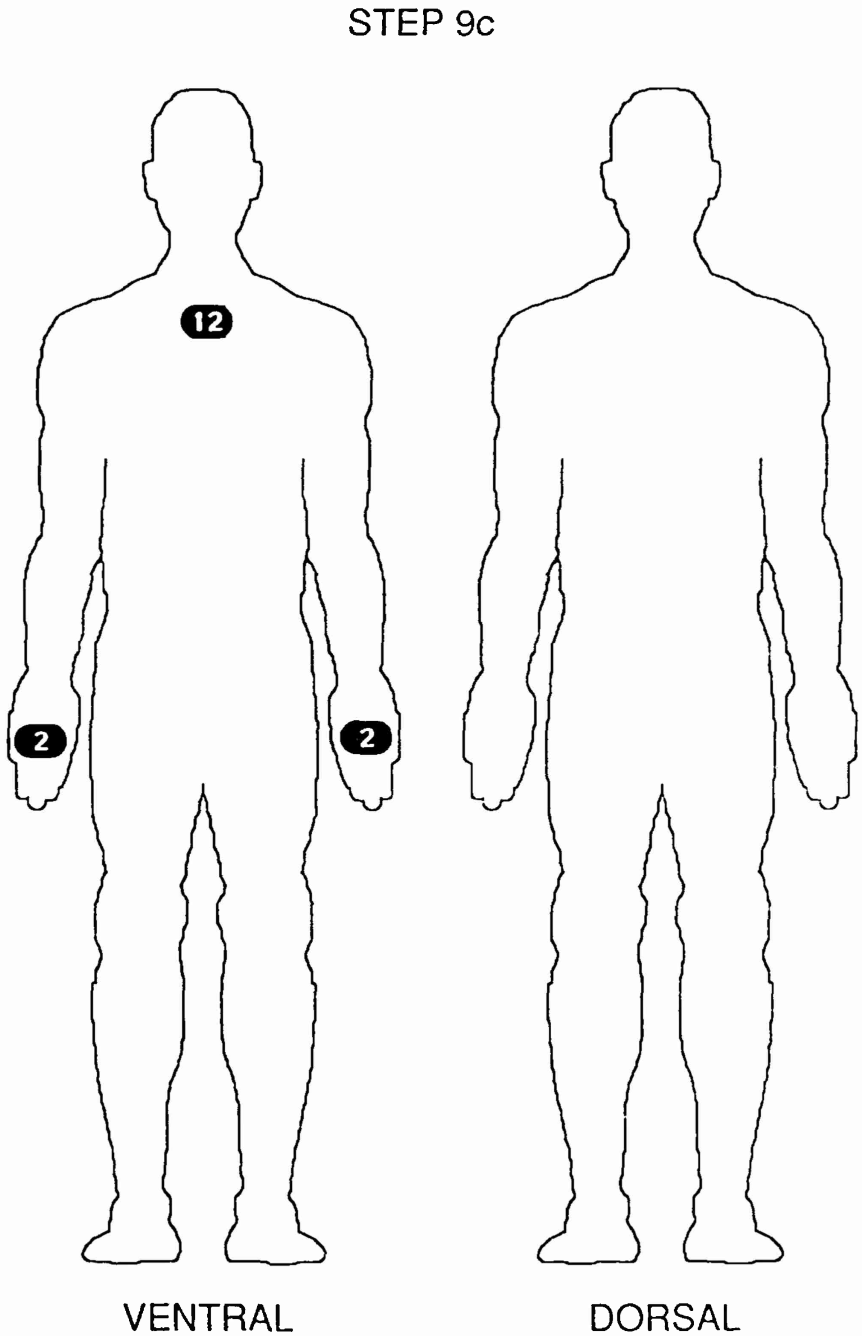


Figure D-13. Somatic map of contamination in Step 9c. The number at each locus identifies the experimental subject who became contaminated there during this step.

STEP 10

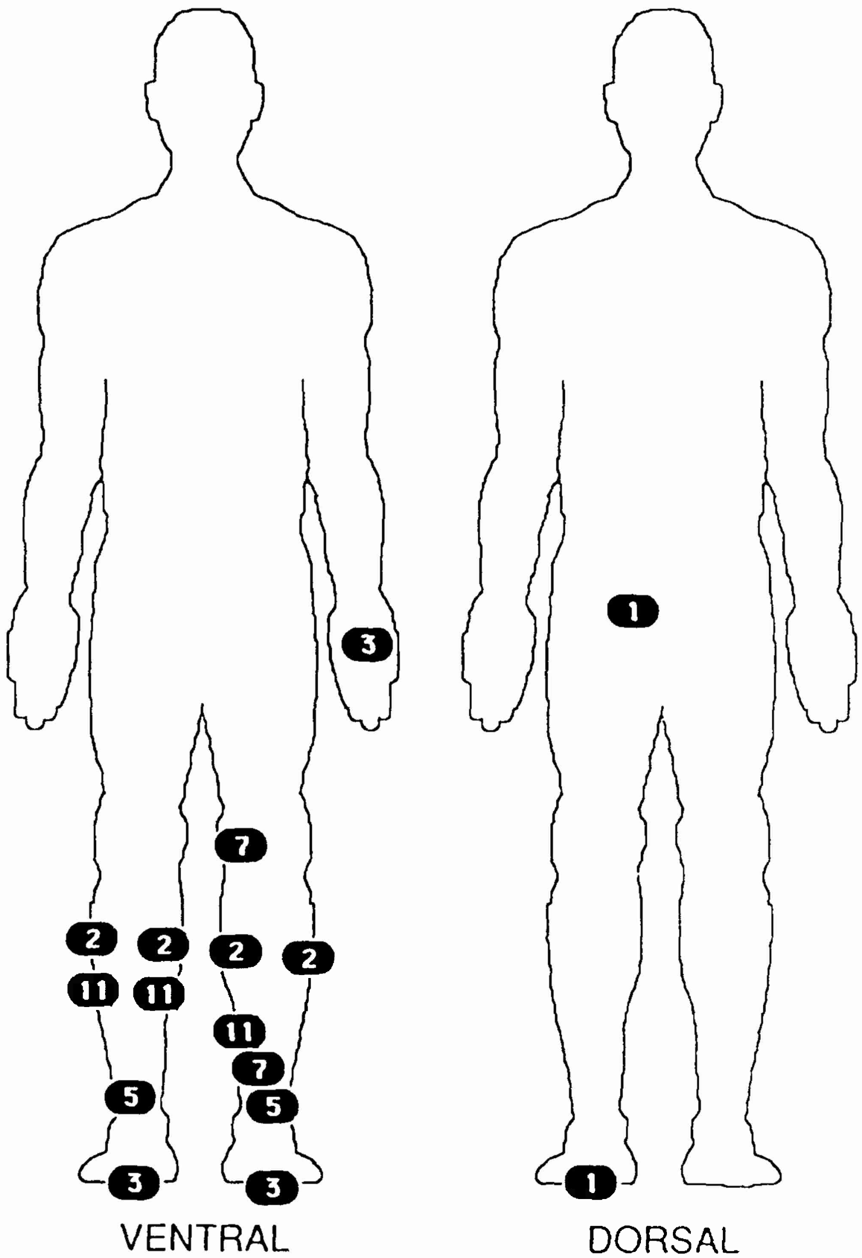


Figure D-14. Somatic map of contamination in Step 10. The number at each locus identifies the experimental subject who became contaminated there during this step.

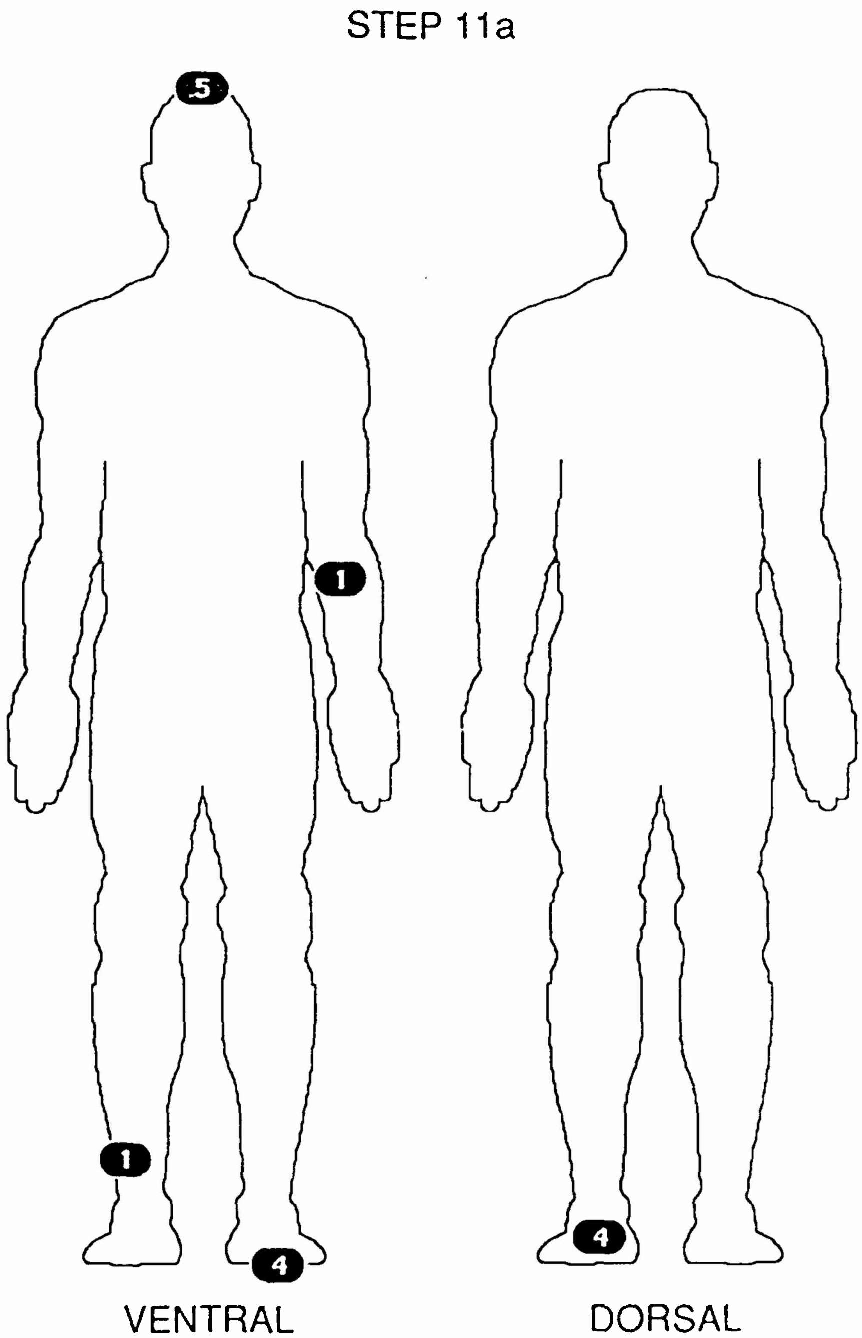


Figure D-15. Somatic map of contamination in Step 11a. The number at each locus identifies the experimental subject who became contaminated there during this step.

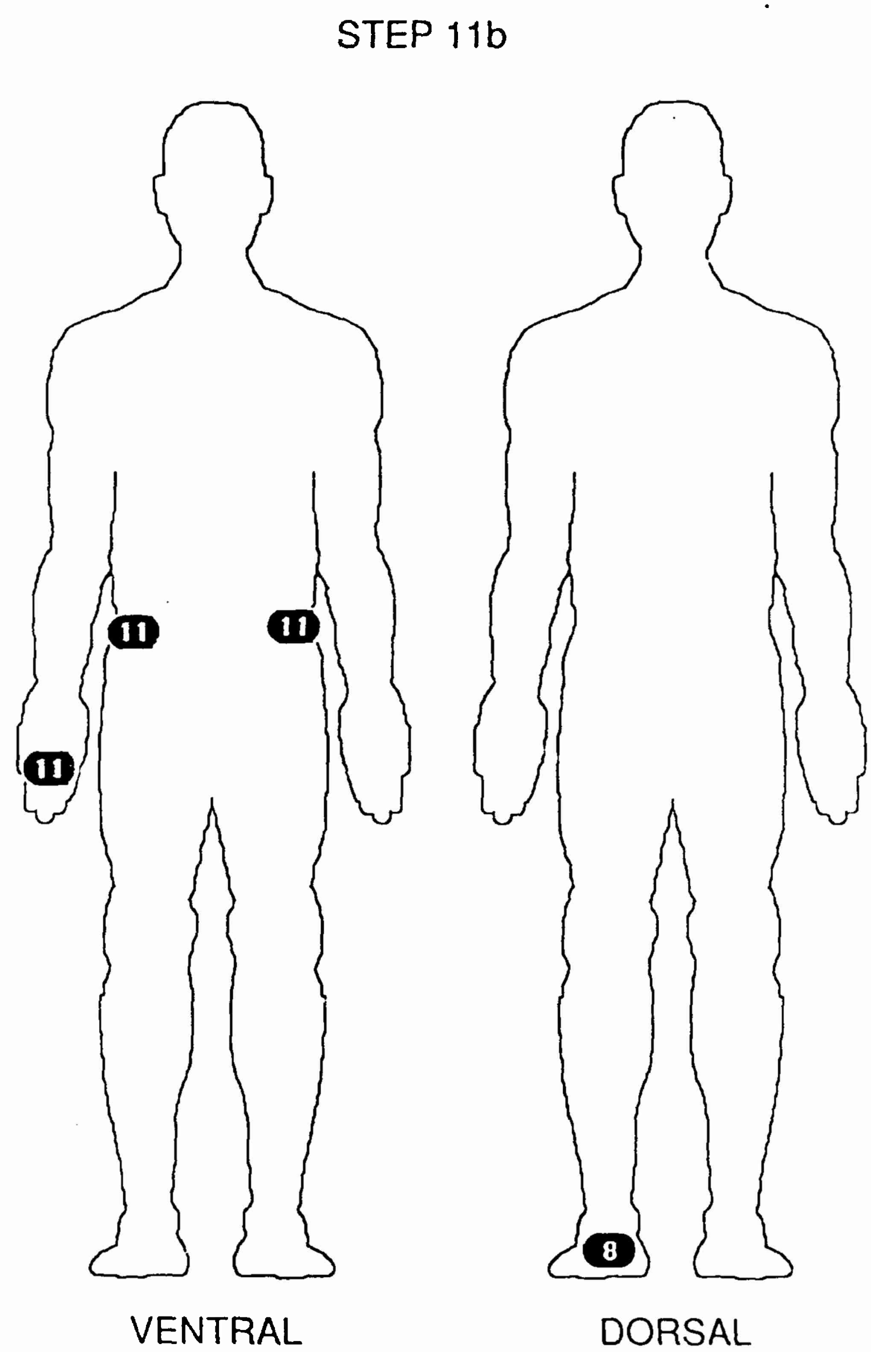


Figure D-16. Somatic map of contamination in Step 11b. The number at each locus identifies the experimental subject who became contaminated there during this step.

STEP 11c

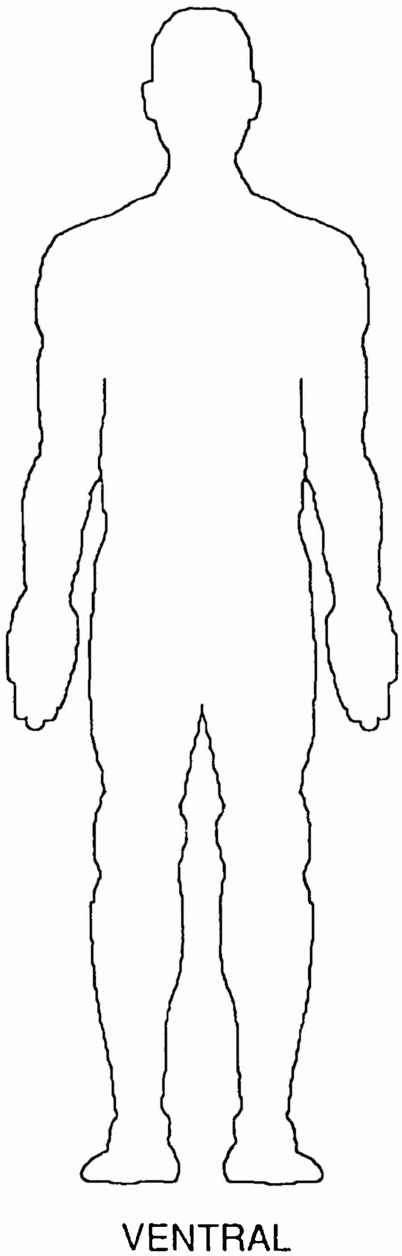


Figure D-17. Somatic map of contamination in Step 11c. The number at each locus identifies the experimental subject who became contaminated there during this step.

STEP 12a

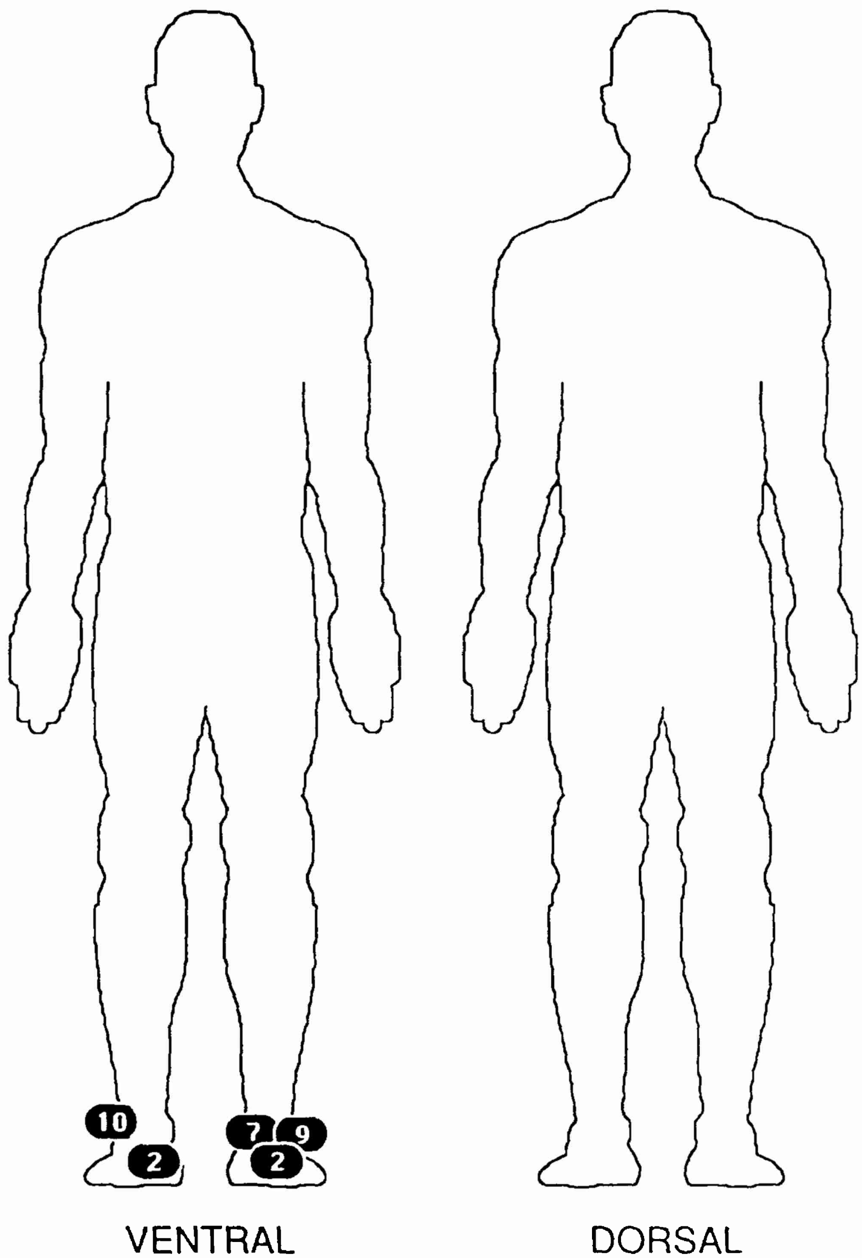


Figure D-18. Somatic map of contamination in Step 12a. The number at each locus identifies the experimental subject who became contaminated there during this step.

STEP 12b

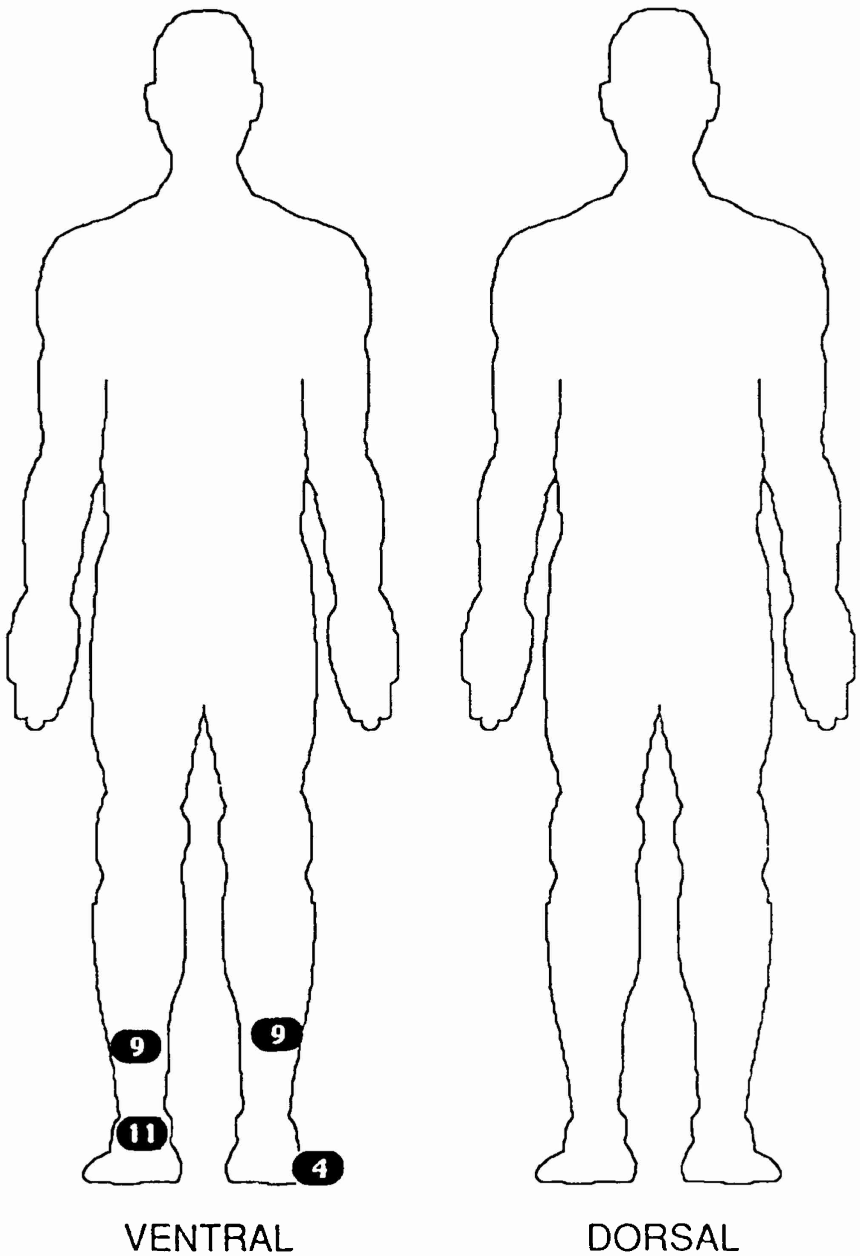


Figure D-19. Somatic map of contamination in Step 12b. The number at each locus identifies the experimental subject who became contaminated there during this step.

STEP 12c

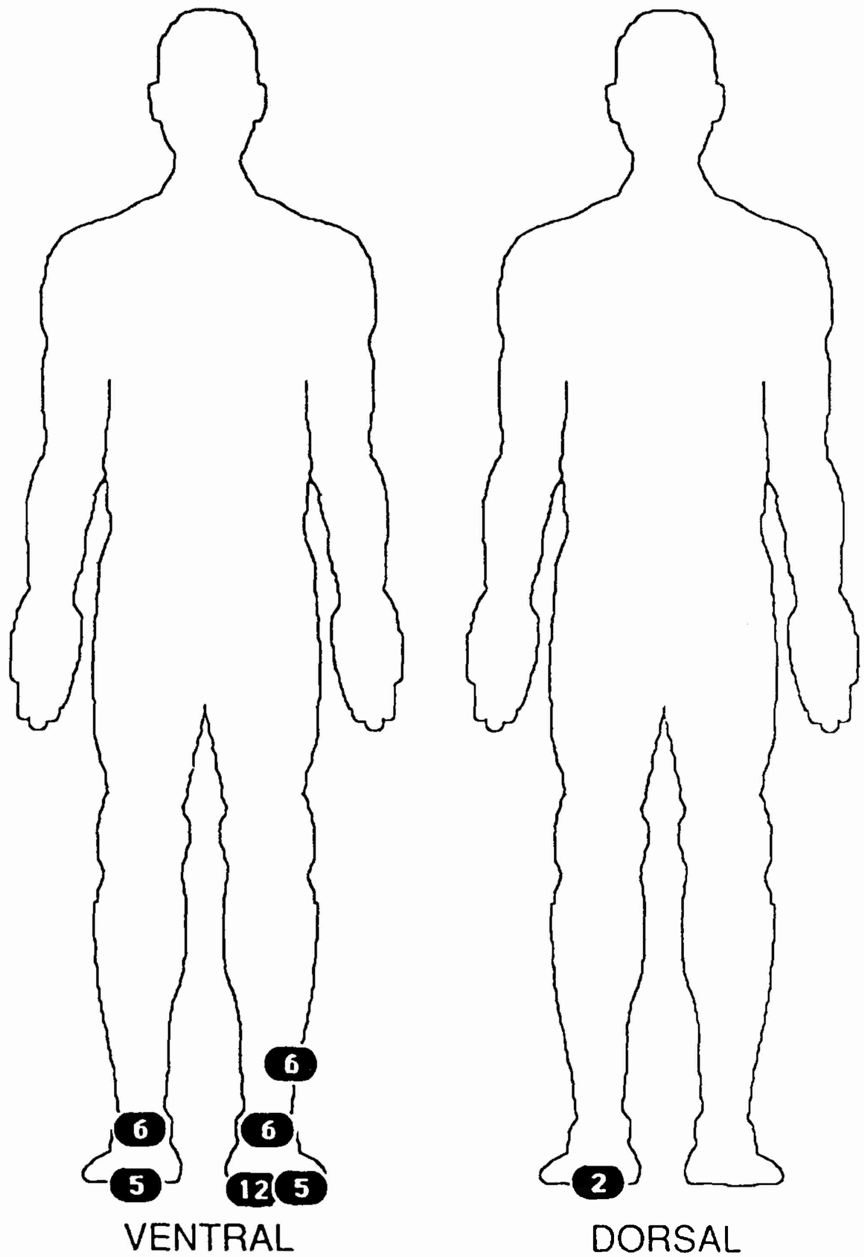


Figure D-20. Somatic map of contamination in Step 12c. The number at each locu^ identifies the experimental subject who became contaminated there during this step.

Appendix E

Somatic Maps of Contamination
Within Subject, Across All Procedural Steps

Appendix E. Somatic Maps of Contamination Within Subject, Across All Procedural Steps

Each of the following figures represents all contaminative (both dermal and nondermal) events that occurred to an individual subject, across all procedural steps of the PCPU hasty decon. The locus of contamination is indicated graphically; the number indicates the procedural step at which it occurred.

Contaminations that are located at the coronal plane or that are otherwise ambiguous as to dorsal/ventral classification are depicted on the linear boundary of the figure. (Examples of such loci include the sole of the foot, the top of the head, and the inside of the ankle.)

The numerosity of these contaminations is equal to or greater than the Total Events for the subject/step, but may be less than the Total Loci data, since closely adjacent traces of simulant cannot be indicated at this scale.

Nondermal contaminations, which occurred only on the foot regions (i.e., the combat boots), can be distinguished from dermal foot contaminations by referring to the step number to determine if the combat boots were on at that point in the decon.

The silhouette is arbitrary and does not represent either the gender or anthropometry of the subjects.

SUBJECT 1

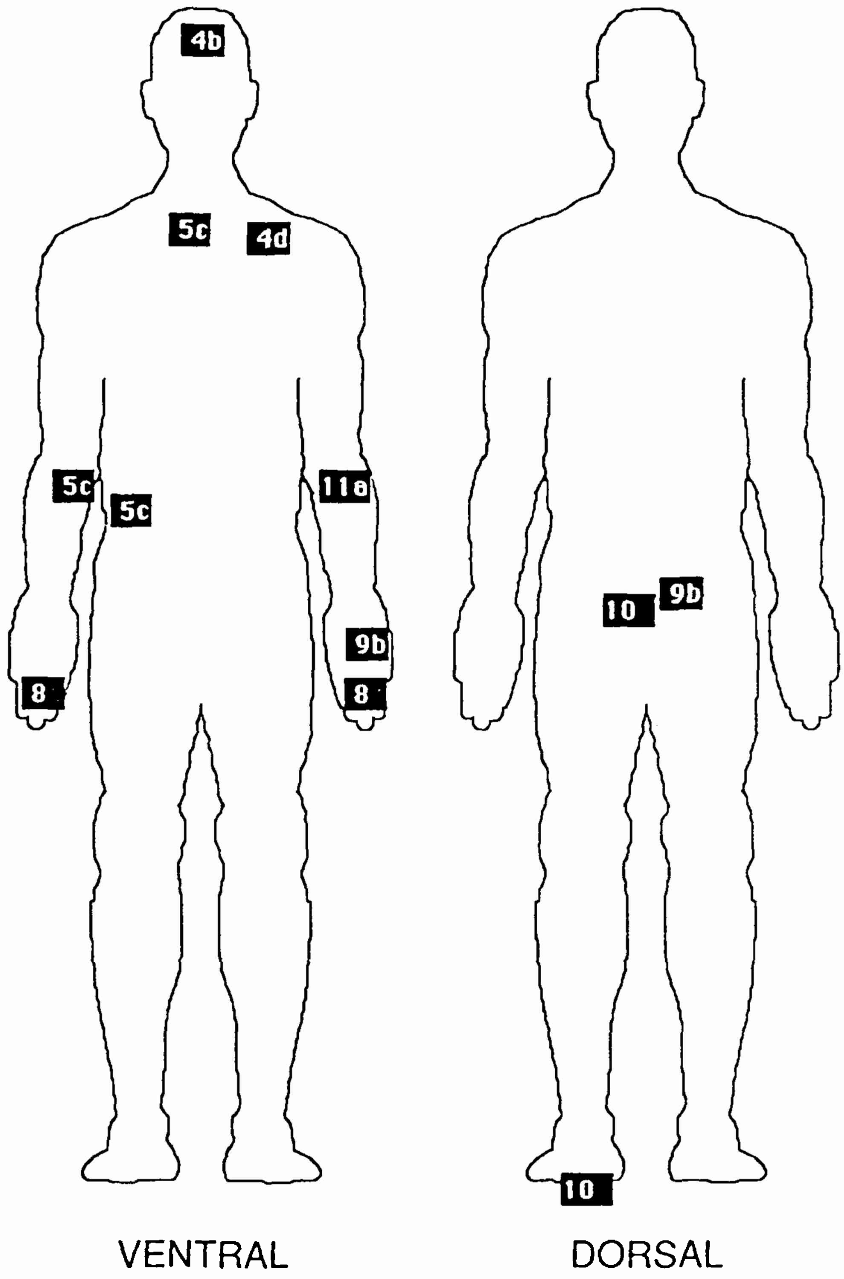


Figure E-1. Somatic map of contamination for Subject 1. The number/letter code denotes the step in which the contamination occurred.

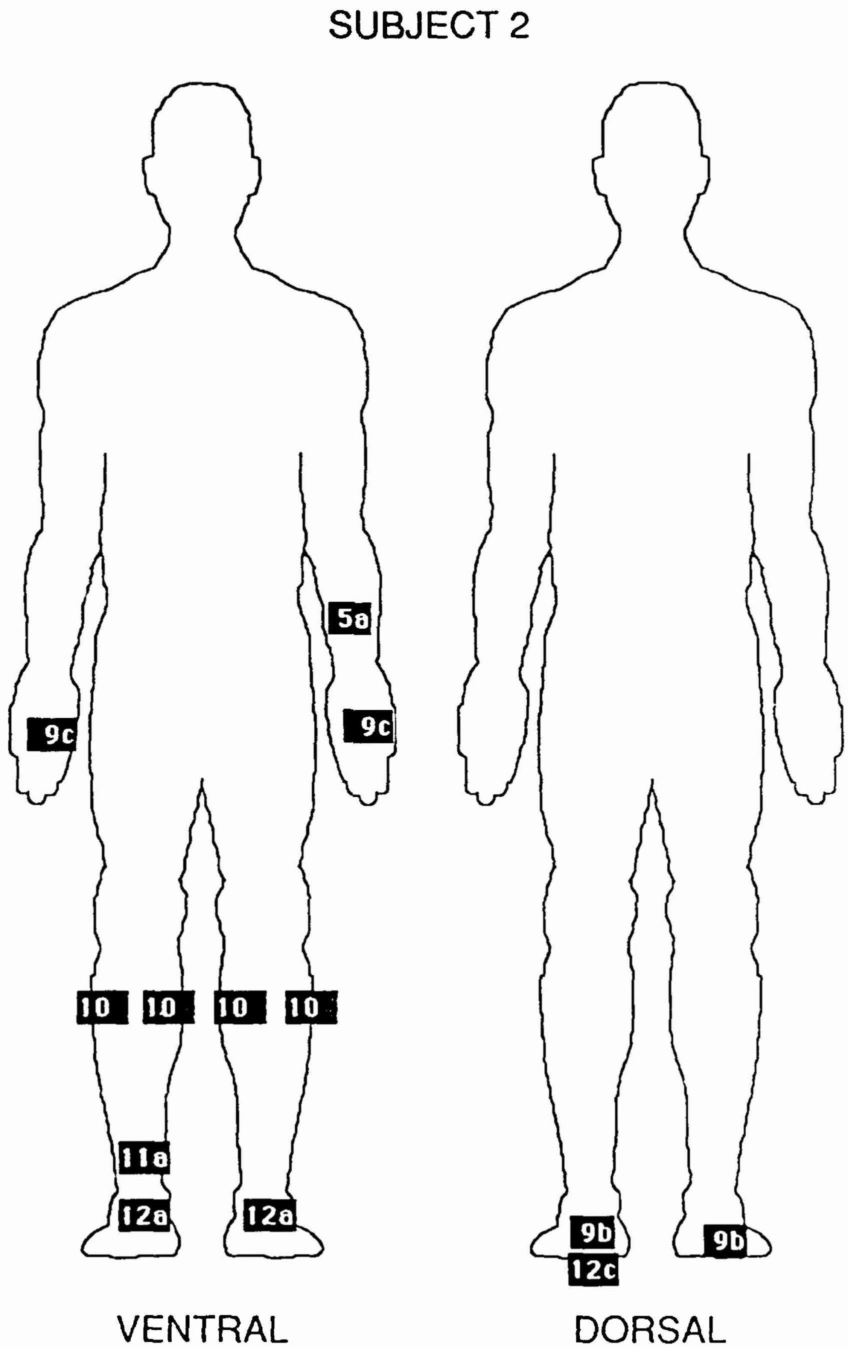


Figure E-2. Somatic map of contamination for Subject 2. The number/letter code denotes the step in which the contamination occurred.

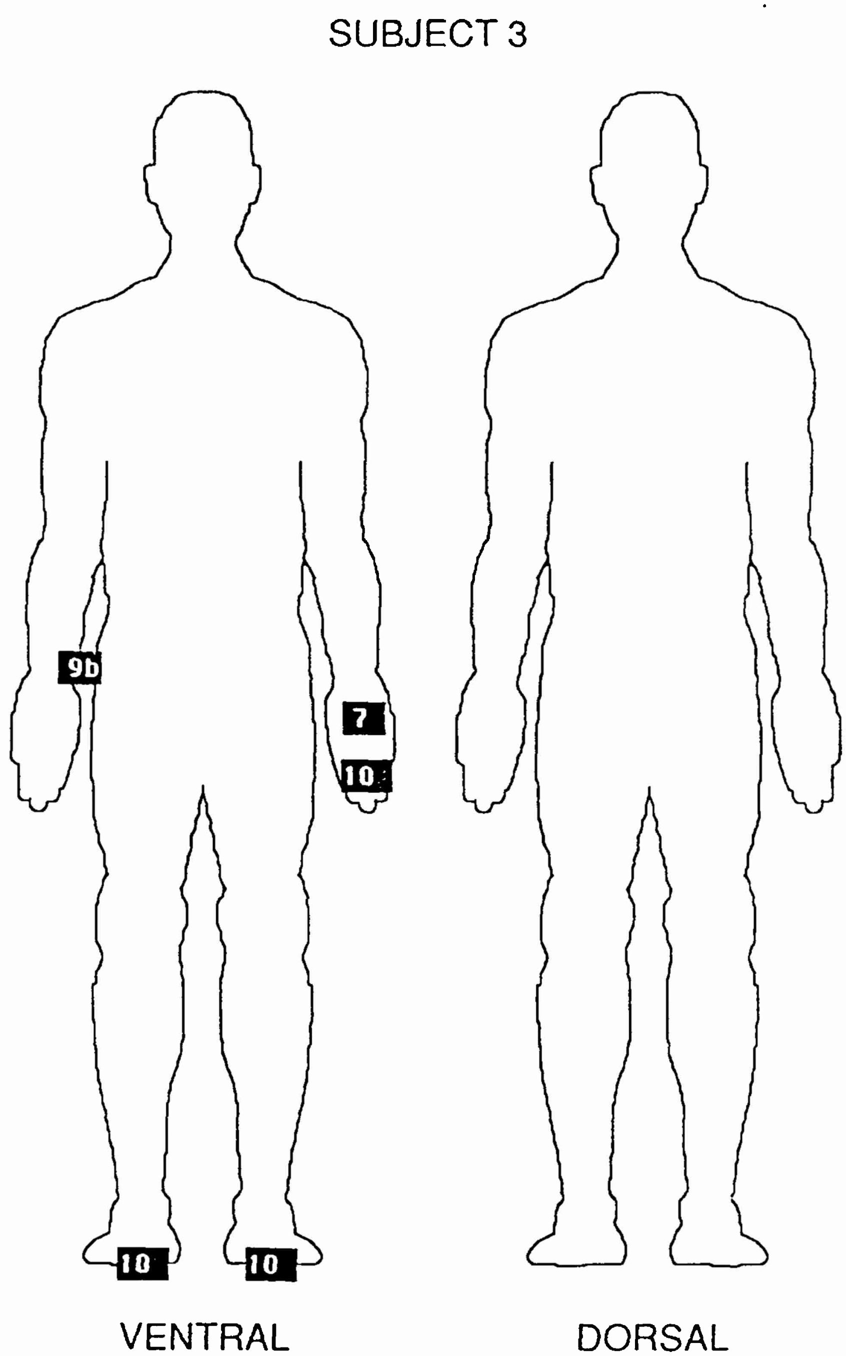


Figure E-3. Somatic map of contamination for Subject 3. The number/letter code denotes the step in which the contamination occurred.

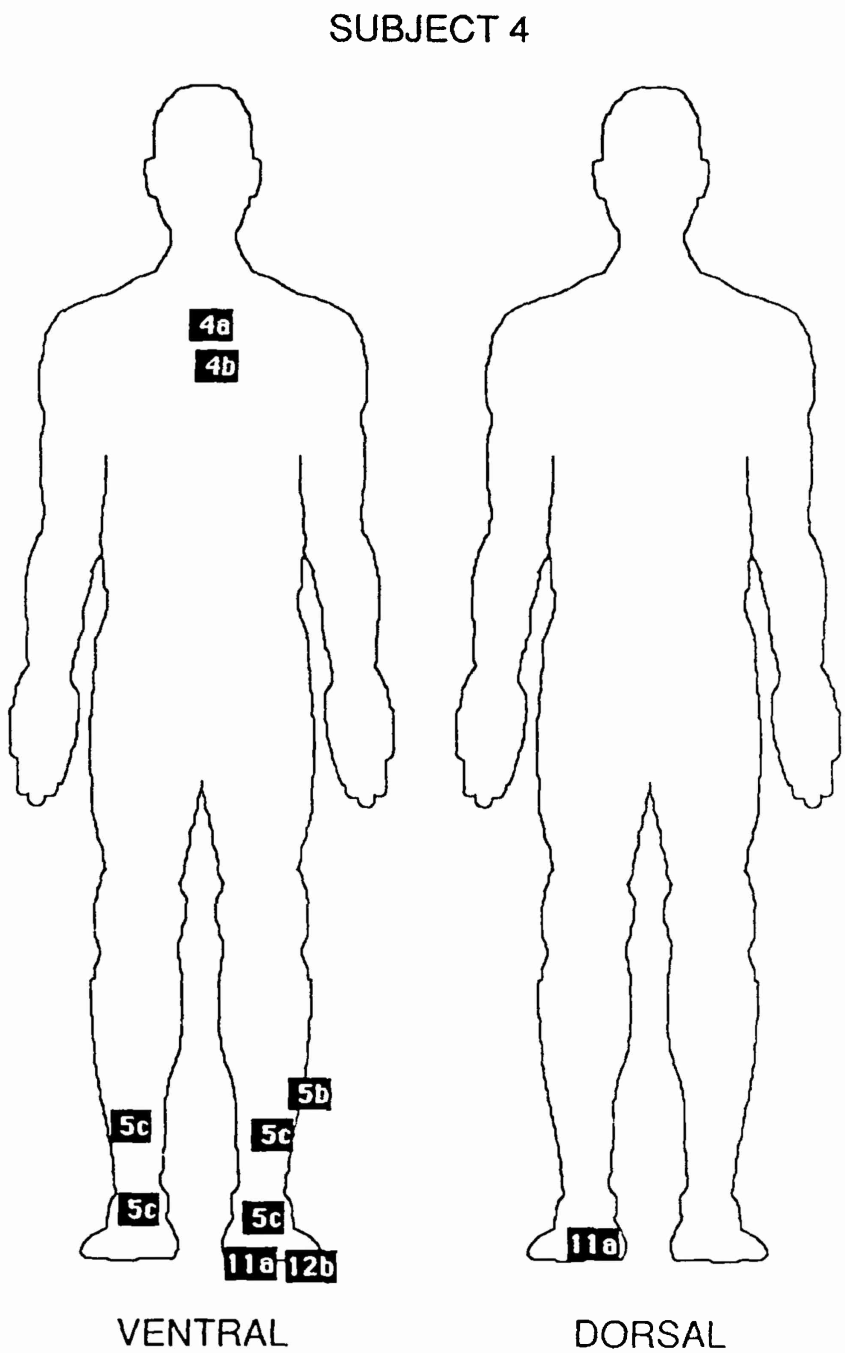


Figure E-4. Somatic map of contamination for Subject 4. The number/letter code denotes the step in which the contamination occurred.

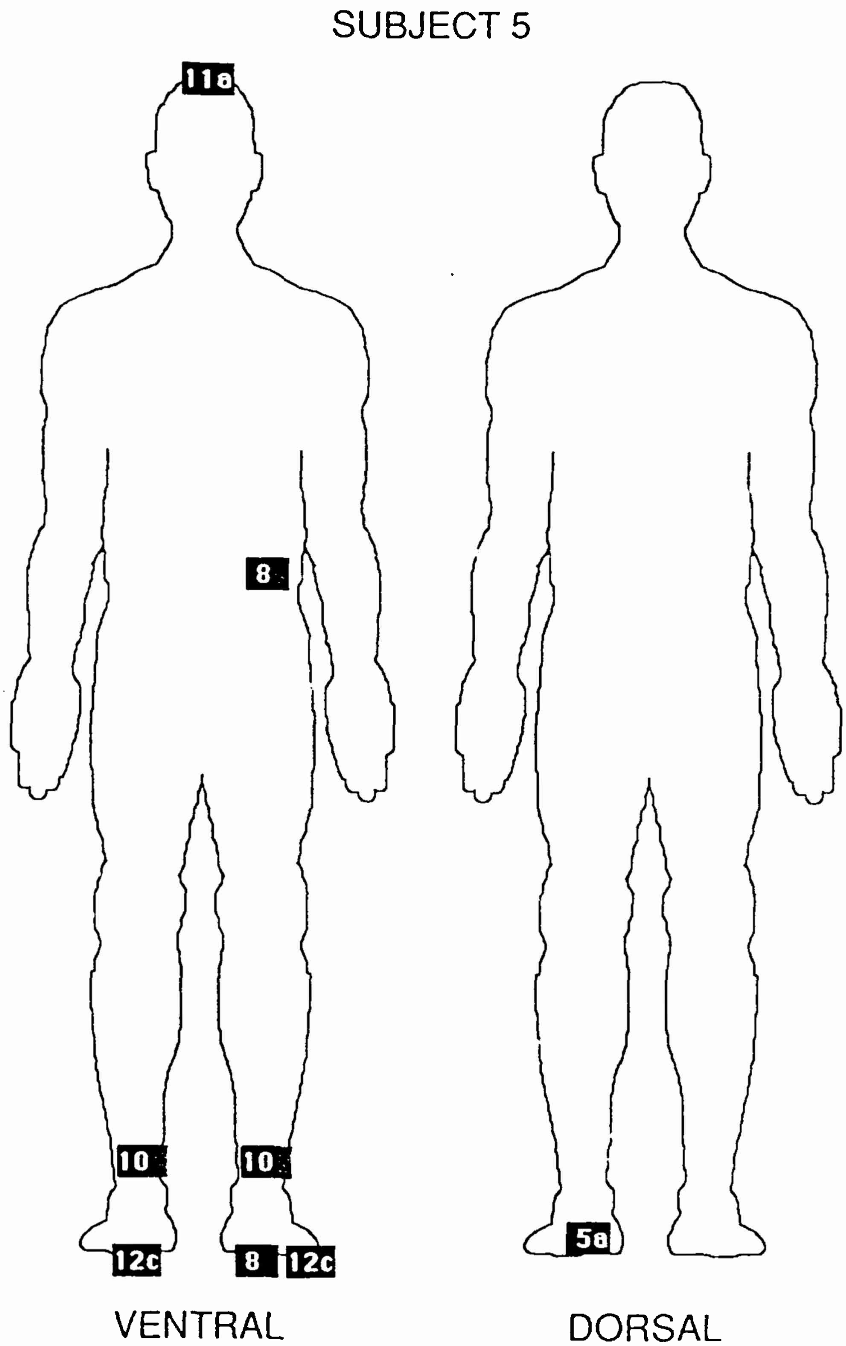


Figure E-5. Somatic map of contamination for Subject 5. The number/letter code denotes the step in which the contamination occurred.

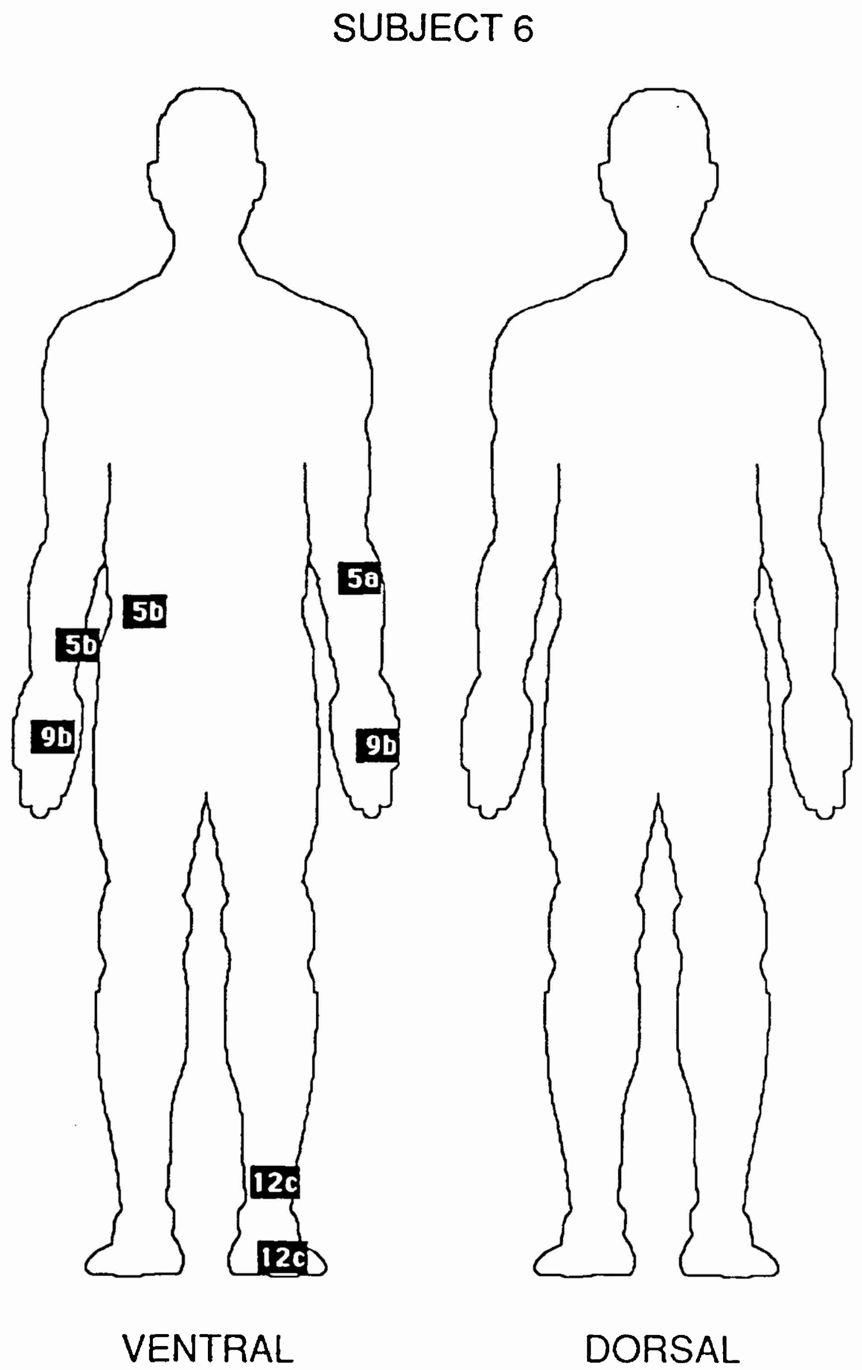


Figure E-6. Somatic map of contamination for Subject 6. The number/letter code denotes the step in which the contamination occurred.

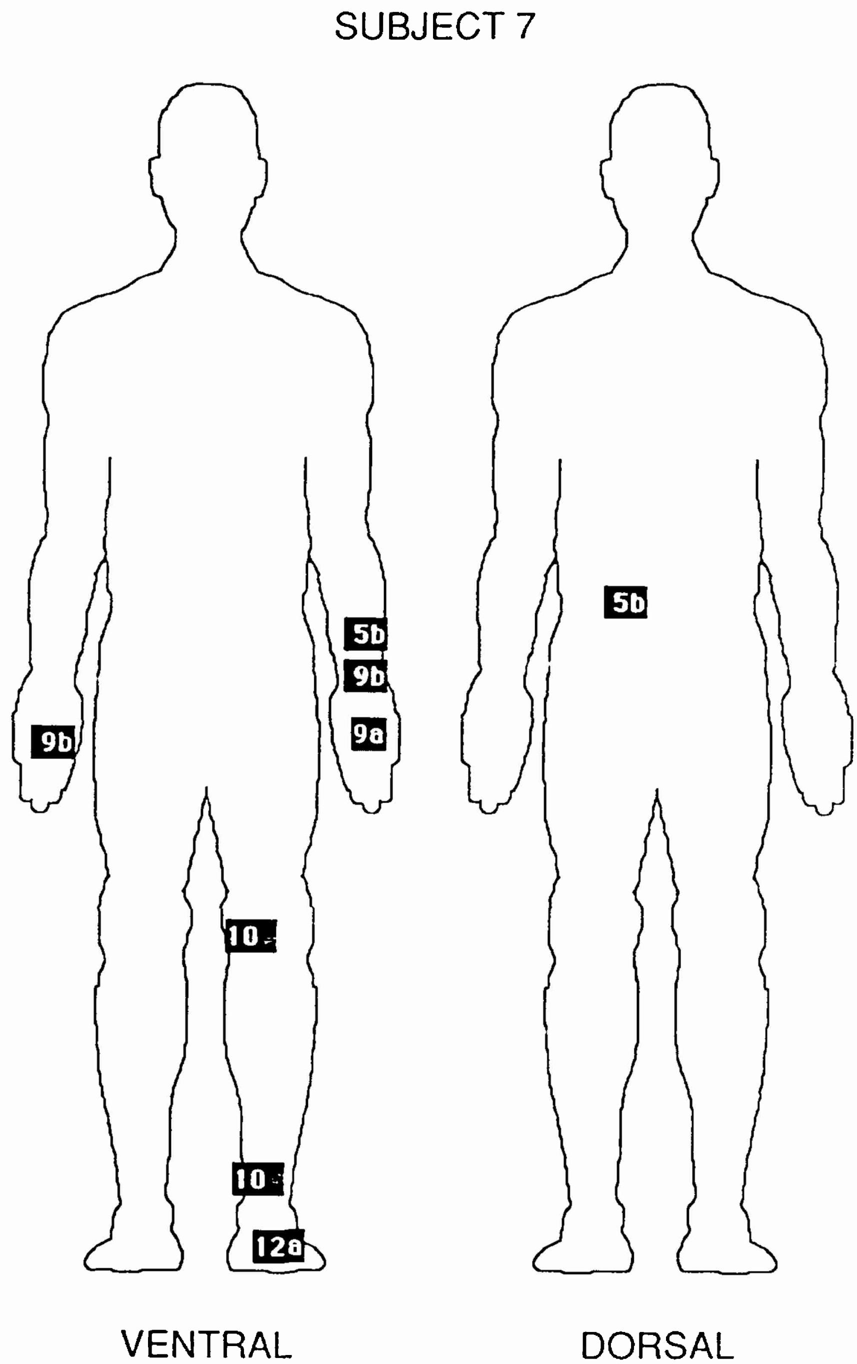


Figure E-7. Somatic map of contamination for Subject 7. The number/letter code denotes the step in which the contamination occurred.

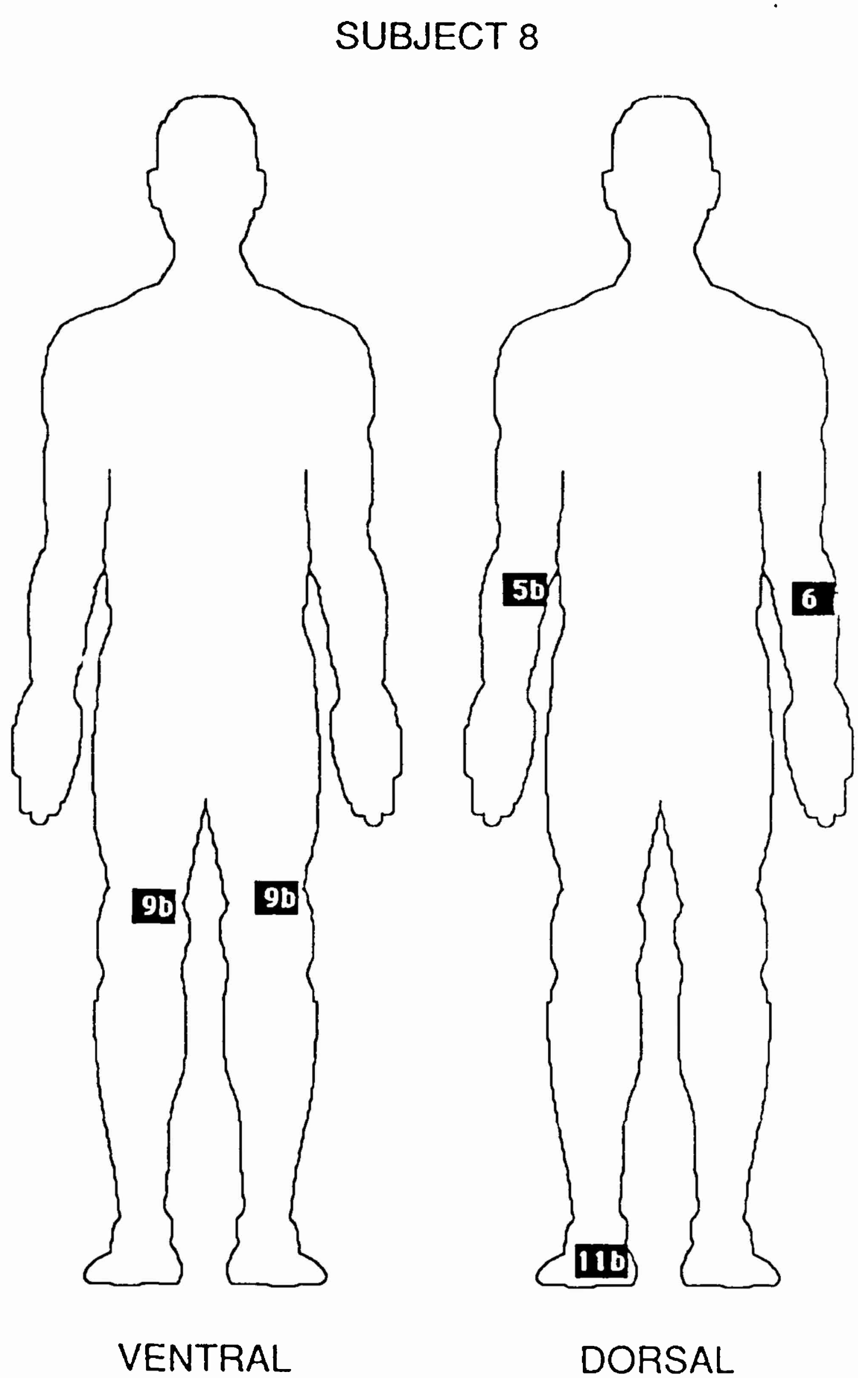


Figure E-8. Somatic map of contamination for Subject 8. The number/letter code denotes the step in which the contamination occurred.

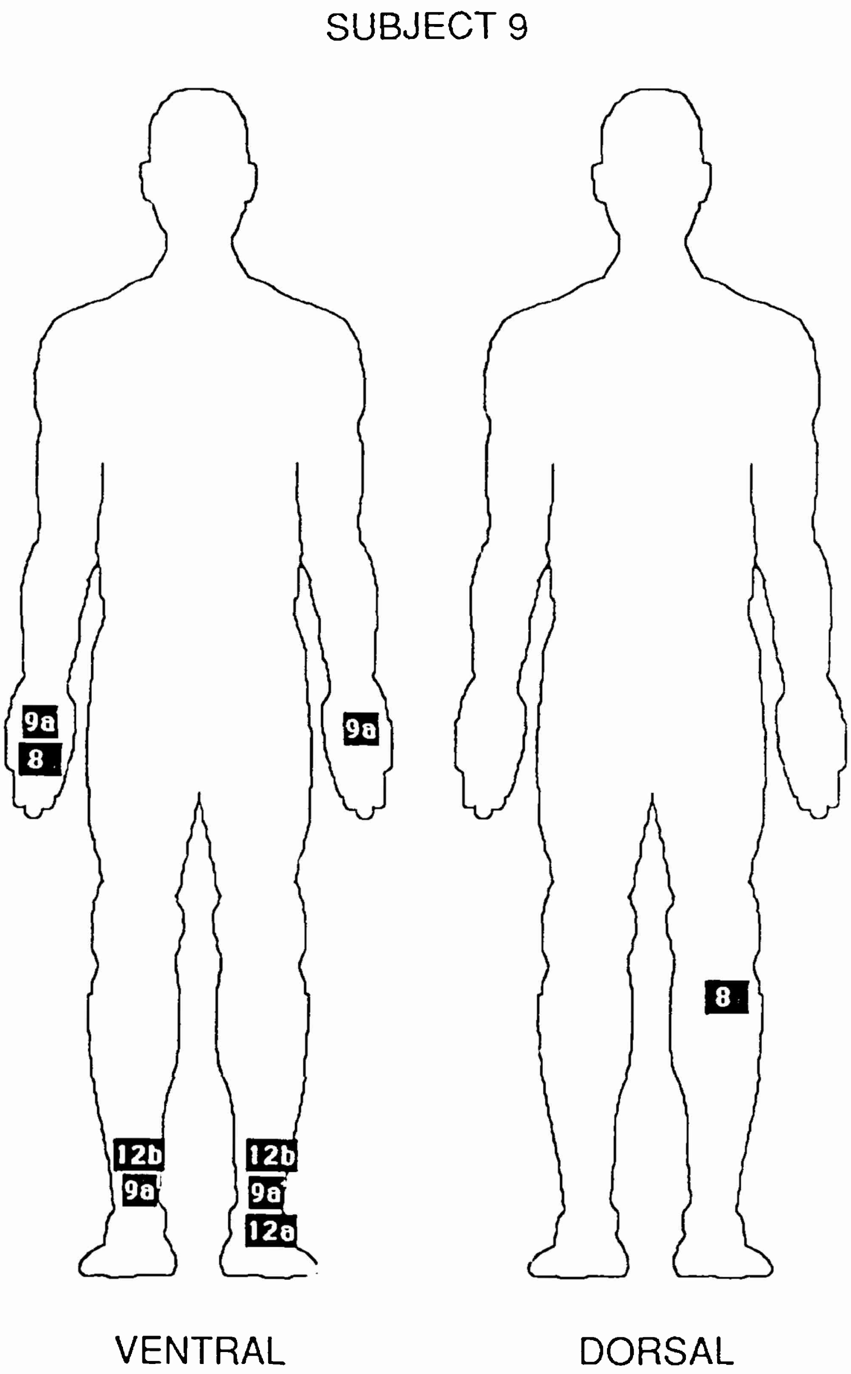
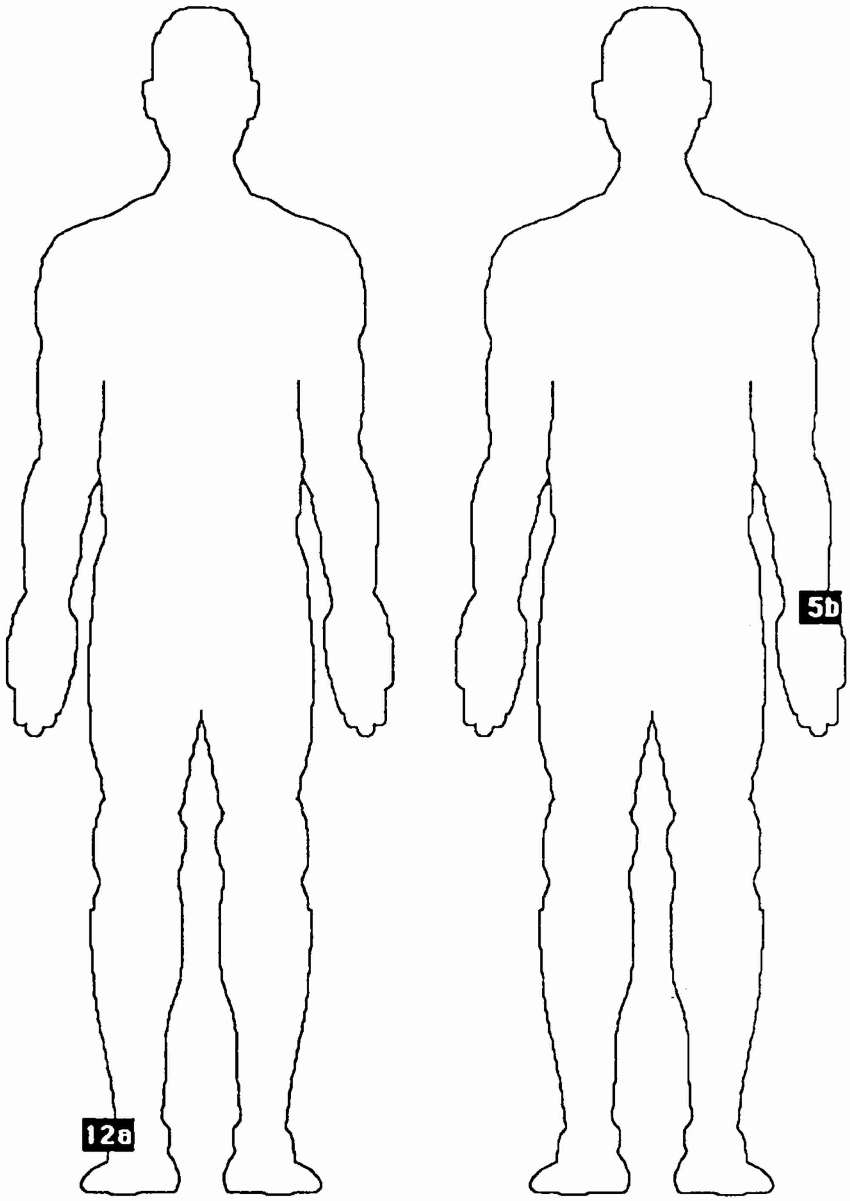


Figure E-9. Somatic map of contamination for Subject 9. The number/letter code denotes the step in which the contamination occurred.

SUBJECT 10



VENTRAL DORSAL

Figure E-10. Somatic map of contamination for Subject 10. The number/letter code denotes the step in which the contamination occurred.

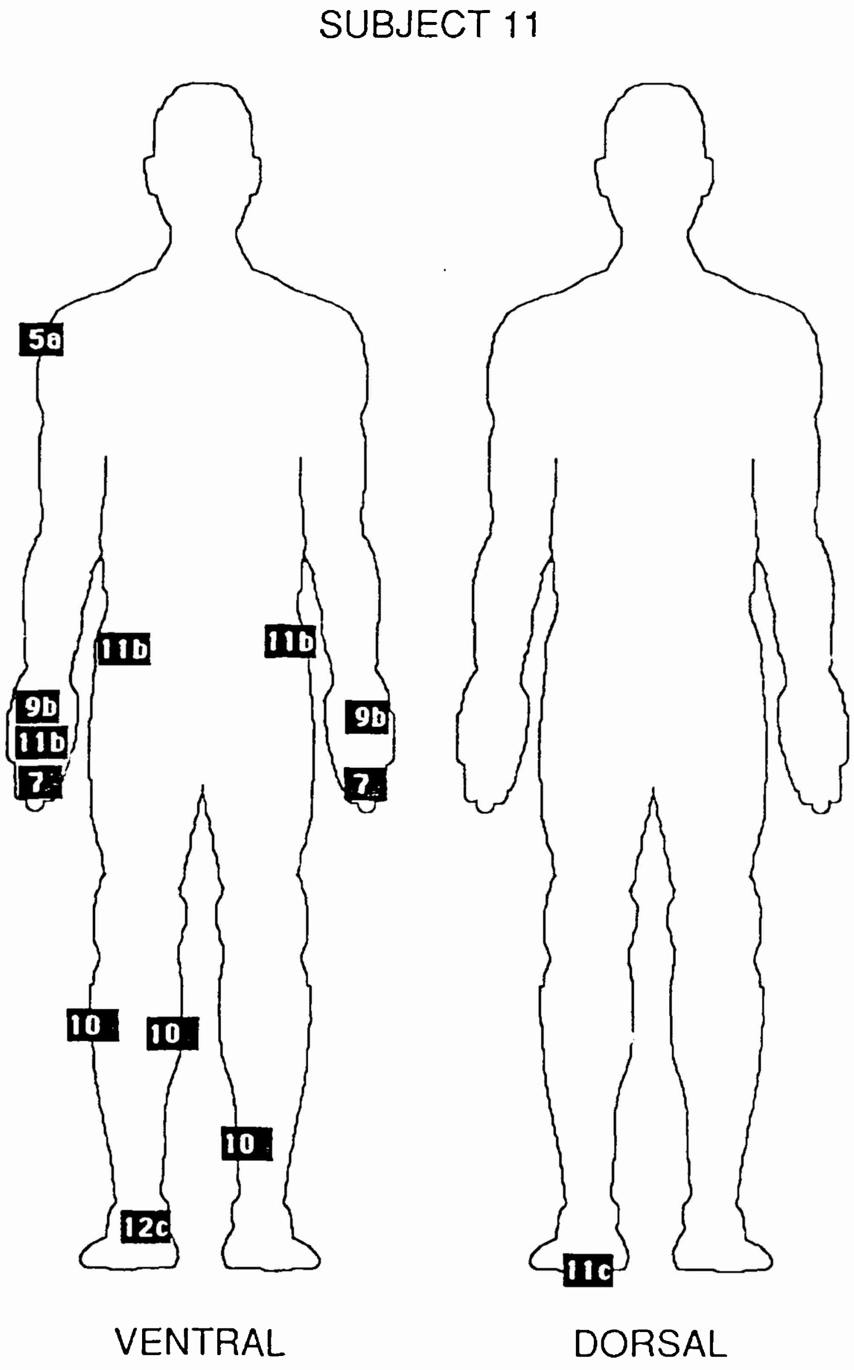


Figure E-11. Somatic map of contamination for Subject 11. The number/letter code denotes the step in which the contamination occurred.

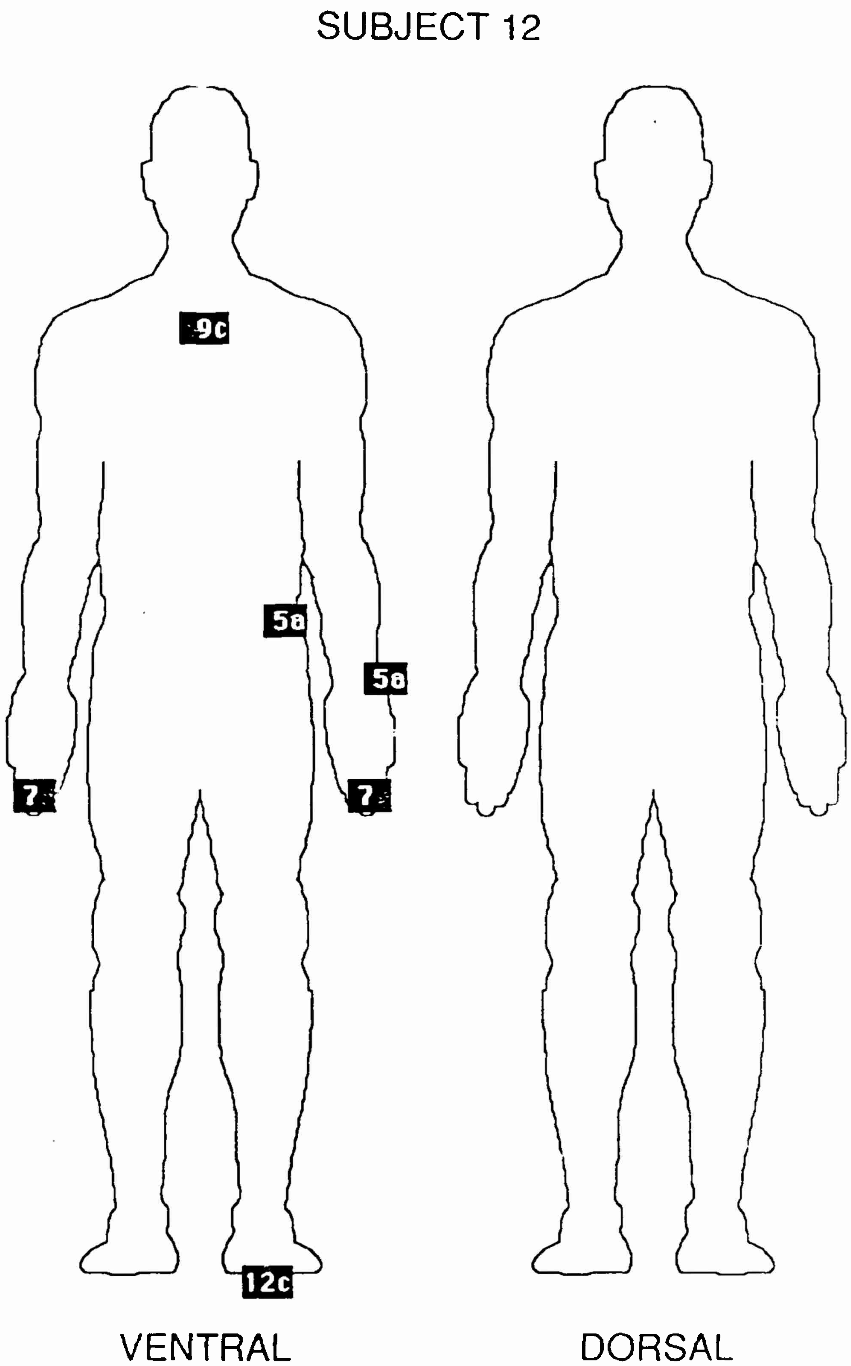


Figure E-12. Somatic map of contamination for Subject 12. The number/letter code denotes the step in which the contamination occurred.

Appendix F

Raw Data from Perceived Hazard Questionnaire

Appendix F. Raw Data from Perceived Hazard Questionnaire

Table F-1. Subjects' (N = 12) Responses to Perceived Hazard Questionnaire (1 = "SAFE", 7 = "HAZARDOUS")

		Pair											
		I		II		III		VI		V		VI	
		Subject											
	Step *	1	2	3	4	5	6	7	8	9	10	11	12
1	Remove BDU coat	3	1	1	1	2	1	4	2	2	1	2	5
3	Decon mask	5	1	1	1	5	1	3	2	1	1	6	1
4a	B. everts pants	3	1	3	3	3	5	5	2	3	1	4	5
4b	Pull off hood	5	1	3	3	3	5	5	3	4	1	7	6
4c	Remove CP top	5	1	1	3	4	7	6	2	4	4	5	6
4d	Spread CP top	4	1	2	3	5	1	3	5	6	6	4	2
5a	Roll pant legs	3	4	2	3	2	7	4	2	6	1	3	6
5b	Decon overboots	3	1	1	3	2	1	4	2	3	1	2	3
5c	Remove overboots	4	6	2	3	2	1	5	2	2	1	2	3
6	Roll BDU pants	3	3	3	6	4	7	5	2	5	1	3	6
7	B. doffs gloves	4	1	2	3	3	1	3	2	2	3	3	7
8	B. lowers CPU	5	3	4	6	5	7	4	3	4	5	5	7
9a	B. sits	4	3	2	5	4	7	6	4	6	7	6	5
9b	B. doffs boots	4	3	3	5	4	7	5	2	6	6	6	4
9c	B. adjusts laces	4	3	2	5	3	2	6	2	6	4	6	1
10	B. doffs lower CPU	5	3	2	5	4	†	3	4	4	4	5	7
11a	B. dons lower CPU	5	3	1	2	3	6	5	2	3	1	2	2
11b	B. dons top CPU	5	3	1	2	3	6	4	2	3	1	2	2
11c	B. dons gloves	4	3	1	2	3	7	3	2	3	1	2	2
12a	B. dons BDUs	3	1	1	2	4	7	4	2	2	1	2	1
12b	B. dons boots	3	1	1	2	4	7	4	3	2	1	5	1
12c	B. dons overboots	3	1	1	2	4	7	3	2	2	1	5	1

* Step 2 ("Decon your own gloves") did not appear on the questionnaire since it did not affect the safety of the soldier in the buddy role.

† This subject failed to respond to this item.

Appendix G

Revised PCPU Hasty Decon Procedure

Appendix G. Revised PCPU Hasty Decon Procedure

Following is the final version of the CPU hasty decon, as modified in accordance with the experimental findings.

Items to be REPLACED:	Chemical Protective Undergarment (2 pc) overboots butyl gloves glove liners BDU trousers BDU coat
Items to be REUSED:	NBC mask combat boots socks conventional undergarments

0. DECON WEAPON AND WEB GEAR

Both you and your buddy do this.

1. REMOVE BUDDY'S BDU COAT

Help buddy remove BDU coat. Buddy clenches fists to retain gloves as arms are withdrawn from sleeves.

Discard the coat.

2. DECON OWN GLOVES

Decontaminate your own gloves.

3. DECON BUDDY'S MASK

Decontaminate your buddy's mask. (If necessary, you may unfasten his or her hood.)

4. REMOVE BUDDY'S CPU TOP

4a) Buddy undoes waist-tabs and fly of BDU trousers, and turns down waist and seat portion inside-out to crotch level. Assist if needed.

4b) Unfasten buddy's hood. Pull edge of hood forward and fold it back about 1 inch. Unzip buddy's CPU top. Grasp back of buddy's hood, and carefully pull it off head.

4c) Have buddy clench fists to retain gloves. Remove buddy's CPU top, letting the garment turn completely inside-out. Both of you must not touch the inner lining.

4d) Spread CPU top on ground with inside surface facing up, and arms spread out. The lining of this garment will be a "safe zone" for your buddy to sit on later; be careful not to contaminate it.

5. REMOVE BUDDY'S OVERBOOTS

Caution your buddy to hold his or her arms up (elbows high) to keep from touching you in the following steps.

5a) Roll up buddy's BDU trouser legs to just below knees.

5b) Decontaminate the upper shaft of buddy's overboots around the opening.

5c) Have your buddy stand next to the safe zone. Carefully remove buddy's overboots; buddy steps onto safe zone as each foot is withdrawn.

6. ROLL BUDDY'S TROUSERS

Roll down the hip and thigh portion of buddy's trousers to just above the knee level.

7. BUDDY REMOVES CP GLOVES

Your buddy removes his or her CP gloves; liners can be retained for slight protection until replaced. Assist as needed with glove removal.

<u>Discard</u> the gloves.

8. BUDDY TURNS DOWN LOWER CPU

Buddy slips hands inside CPU waistband, spreads waistband, and turns garment down over knees to cover bunched-up BDU trousers. The CPU and the BDUs should form a bundle about the knees, with only the inside lining of the CPU exposed.

Your buddy is now in a very vulnerable state. At this point <u>you</u> are the biggest threat to your buddy, so exercise caution from this point on.

9. BUDDY REMOVES COMBAT BOOTS

9a) Have your buddy sit on the safe zone, unassisted.

9b) Instruct your buddy to carefully remove his or her combat boots, without letting the laces touch the ground. Your buddy places each boot on an arm of the safe zone.

9c) Remind your buddy to readjust bootlaces for redonning (because boots will be put on while gloved).

10. HELP REMOVE LOWER CPU AND BDU PANTS

Buddy inserts <u>right hand</u> down <u>inner</u> side of the <u>left leg</u> of the CPU, and grasps top of sock. Left hand goes inside CPU down <u>outer</u> side of left leg and spreads CPU cuff opening. While holding onto sock, buddy removes left leg from bundled pants/CPU. Garment bundle must not come undone. You may help buddy if needed, being careful not to touch his or her feet.

Buddy repeats with opposite leg.

If you do not touch the outside of the bundle (i.e. the uncontaminated lining of the lower CPU), then it may be set aside for use as additional safe-surface support. If you have touched the outside of the bundle, <u>discard</u> it.

11. NEW CPU AND GLOVES

Have your buddy stand up.

Open a new CPU package without touching the garments inside. Buddy extracts the new CPU without touching the outside of the package, and sets aside the CPU top on the safe zone.

11a) CP bottom: Buddy dons new CPU bottom; while he or she does this, you open new CP glove/boot package without touching contents.

11b) CP top: Buddy dons new CPU top and fastens hood; leaves top untucked outside of CPU waistband.

11c) CP gloves: Buddy discards old glove liners if they are still on. Buddy extracts new CP liners and gloves without touching outer package, and dons them. Gloves go outside of CPU sleeve.

12. NEW BDU, OLD COMBAT BOOTS

Open new BDU package without touching contents. Buddy extracts new BDU without touching outer package.

12a) Buddy dons new BDU trousers, being careful not to let them touch the ground. CPU top is tucked into BDU waist (not into CPU waist).

12b) Instruct your buddy to adjust the lacing of his or her combat boots and then redon them.

12c) Buddy extracts new CP overboots without touching outer package. Laces must not drag on ground. Your buddy dons the new overboots.

12d) Buddy dons new BDU coat. Sleeves go outside of gloves.

13. SWITCH ROLES

If only ONE of you has been deconned, then switch roles with your buddy and repeat from step 1.

If BOTH of you have been deconned, then proceed to step 14.

14. GLOVE DECON

The soldier who was the <u>first</u> to be deconned now decontaminates his or her own gloves.

15. CONCEAL TRACES and/or TAG WASTE HAZARD, AS APPROPRIATE

* * * DONE * * *

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